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THE TIROS VIII METEOROLOGICAL SATELLITE SYSTEM

POST-LAUNCH EVALUATION REPORT

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Prepared for the

GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
WASHINGTON, D.C.

By the

ASTRO-ELECTRONICS DIVISION
DEFENSE ELECTRONIC PRODUCTS

RADIO CORPORATION OF AMERICA

PRINCETON, NEW JERSEY

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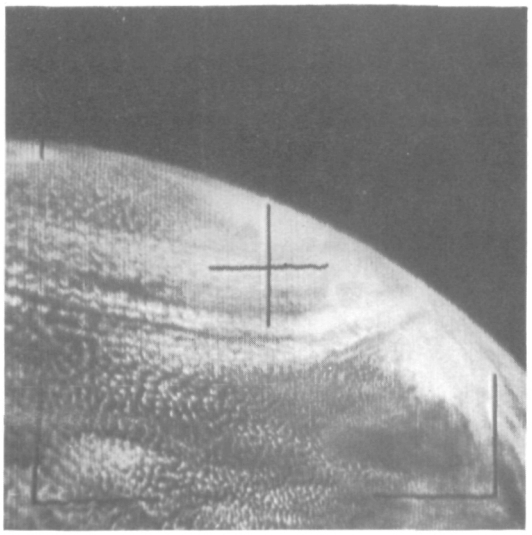
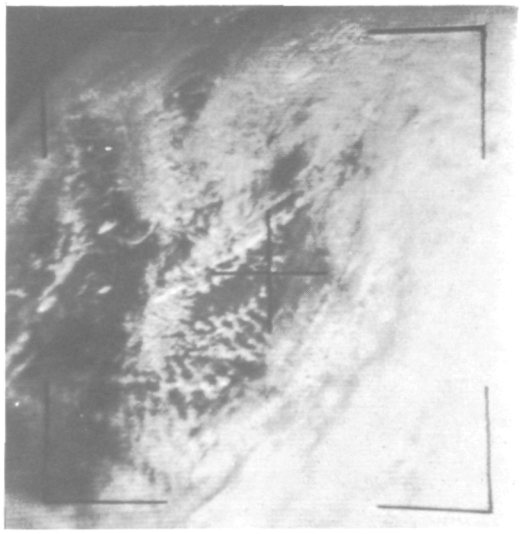


Orbit 11,695, Camera 1, Tape
(806 Days in Orbit)



Orbit 11,796, Camera 1, Tape
(813 Days in Orbit)

TIROS VIII Pictures Taken After More Than 26 Months of Operation in Orbit

PREFACE

This report contains the results of the Post-Launch Evaluation Program for the TIROS VIII Meteorological Satellite System from the date of launch to the end of 24 months of operation in orbit. The TIROS VIII evaluation program has been conducted for the Goddard Space Flight Center of the National Aeronautics and Space Administration by the Astro-Electronics Division (AED) of the Radio Corporation of America, under contract No. NAS 5-1335.

The TIROS VIII satellite was launched from Cape Kennedy, Florida, on December 21, 1963 and, as of May 25, 1966, after a period of more than 29 months, remains capable of providing meteorologically useful pictures from orbit. The quality of the data returned by TIROS VIII after more than two years of operation in space is shown in the representative pictures reproduced on the facing page.

In addition to the regular operational interrogations, periodic interrogations of TIROS VIII have been conducted by RCA engineers to evaluate satellite performance and to investigate any changes in performance capability or quality. In addition, theoretical analyses and tests have been conducted to determine the most probable causes of performance changes. Such analyses and tests have been instrumental throughout the TIROS program in continuing the advancement of satellite and ground-station equipment design and in the refinement of ground-station operations and data-processing techniques.

During the months preceding publication of this report the TIROS VIII satellite was not used to provide meteorological data because of the availability of data from TIROS X and ESSA 1. At the time of publication of this report TIROS VIII was being maintained on a standby basis and was being programmed on only one orbit each day.

Brief functional descriptions of the satellite subsystems and of the ground-station equipment are included in this report. More detailed descriptions and additional information concerning the design and technical development of the TIROS system are contained in or referred to in the TIROS VIII final engineering report. Other documents which may be useful to the reader of this report are referred to in the text.

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I. INTRODUCTION

On December 21, 1963, at 09:30.00.24 GMT (4:30.00.24 EST), the TIROS VIII meteorological satellite was launched from Cape Kennedy, Florida, and injected into a circular, prograde orbit with apogee at 468.37 statute miles and perigee at 434.95 statute miles. The orbit was inclined at 58.5 degrees to the earth's equator and the anomalistic period of the satellite was 99.35 minutes. Within several orbits, full operational capability of the satellite's subsystems was demonstrated, and TIROS VIII thus became the eighth consecutive spacecraft in the TIROS program to achieve successful orbital operation.

The TIROS VIII program was carried out with a twofold purpose: (1) the picture coverage of the satellite supplemented the TV weather coverage provided by TIROS VII (which, at the time TIROS VIII was launched, was fully operational with no signs of degradation after 6 months of operation in orbit), and (2) it provided advanced operational evaluation, on an experimental basis, of a direct-readout camera subsystem and associated ground receiving stations designed for the first Nimbus meteorological satellite*. The direct-readout camera subsystem is designated the Automatic Picture Transmission (APT) subsystem and is designed to provide local TV meteorological picture coverage by direct transmission to relatively simple, passive APT ground stations located throughout the world. Approximately 45 APT stations were in use during TIROS VIII APT operation.

After 24 months in orbit, the standard TIROS camera subsystem of the TIROS VIII satellite continued to produce pictures useful for meteorological purposes.

The standard TIROS camera subsystem returned 97,156 pictures in its first 24 months in orbit, i.e., through December 31, 1965, of which 89,963 (92.6 percent) were useful for meteorological analysis. From the useful pictures, 2825 nephanalyses were prepared and 799 storm advisories and bulletins (an average of more than one per day) were issued.

The APT camera subsystem provided usable pictures until May 22, 1964, when, after five months of operation in orbit, a gradually increasing loss of contrast finally rendered the images too indistinct for interpretation. The APT subsystem returned a total of 4,044 TV pictures in the five-month period. Meteorological analyses were not performed on the APT pictures because of the experimental nature of the system.

*Nimbus I was launched on August 28, 1964.

In addition to the TIROS and APT television subsystems, TIROS VIII carried an instrumentation control subsystem, a beacon and telemetry subsystem, a dynamics control subsystem, a power supply subsystem, and attitude sensing devices. Electrical energy for operation of the subsystems was supplied by a solar-energy conversion array, which covered the exterior of the satellite except for the baseplate, and storage batteries, which provided electrical energy during periods when the solar array was not illuminated by the sun.

This report is organized to present a summary evaluation of the overall TIROS VIII system and the associated ground operations (Section II) and a separate detailed evaluation of the performance of each satellite subsystem and each ground station installation (Sections V through XIII). A brief description of the TIROS VIII system design is also included (Section IV) as well as a brief functional description of each of the subsystems (preceding the evaluation discussions in Sections V through XIII) to provide background information for the evaluation discussions. Where it has been necessary to include design detail in an evaluation discussion, the reader may find it desirable to refer to the TIROS VIII final engineering report for diagrams and other data pertaining to details of spacecraft design.

A discussion of the role of TIROS VIII in collecting meteorological data is presented in Section III of this report. Section III is intended to provide a brief chronology of TIROS VIII's role of observing world weather patterns and storms and to present a representative group of the TV pictures taken by the satellite. The pictures have been selected for their general meteorological interest as well as to show the performance of the camera subsystems at different periods in the satellite's operational life. Pictures have been chosen which exhibit the satellite's capability for photographing cloud patterns, land masses, coast lines, mountainous areas, and other features of the earth and the earth atmosphere that are detectable by satellite television.

II. EVALUATION SUMMARY

The TIROS VIII spacecraft was launched from Launch Pad 17B at Cape Kennedy, Florida on December 21, 1963. Some minor difficulties with the launch vehicle were encountered preparatory to the launching, forcing postponements of the launching on December 16, 17, and 20. These difficulties were corrected and lift-off took place at 04:30.00.24 EST on December 21. All three rocket stages of the launch vehicle performed normally, and the spacecraft entered a nearly circular orbit with an inclination of 58.5 degrees. The spin rate of the third-stage rocket and spacecraft combination shortly after injection was 128 rpm, slightly above the nominal value of 126 rpm.

The spacecraft separated normally from the third-stage rocket and a normal spin down from 128 rpm to 10.4 rpm was reported to the TIROS Technical Control Center (TTCC) from the Winkfield, England, station of the Minitrack network. The APT station at Lanmion, France, also observed and reported the separation and spin-down events, confirming the values received from Winkfield.

The satellite's beacon signals were received on schedule and at the predicted azimuth by the Pacific Missile Range (PMR) Command and Data Acquisition (CDA) station on the first orbit. The beacon signals were tracked by the PMR station, which also confirmed the separation and spin-down events.

The satellite was interrogated by the Princeton AED back-up CDA station on orbit 001. Direct picture-taking was commanded and pictures of good quality were obtained from the standard TIROS camera subsystem (camera subsystem No. 1) in the direct mode of operation.

On orbit 002, the PMR station conducted its first interrogation of TIROS VIII and successfully received direct camera pictures from subsystem No. 1 and satellite telemetry and attitude data. Remote pictures from camera subsystem No. 1 were first received on orbit 004; these first remote pictures showed that remote picture operation of the satellite was normal and that picture quality was good to excellent. The normal performance and high picture quality of camera subsystem No. 1 continued through 22 months of the evaluation period covered in this report. After that time, camera subsystem No. 1 continued to function normally, although picture quality declined somewhat.

The world's first readout of an APT camera subsystem took place on orbit 004 over East Coast APT stations. The APT program sequencing equipment aboard the satellite responded normally, and three APT pictures were received by the ground stations. Although the solar elevation angle was somewhat low for picture taking, the APT video quality was good. However, it was immediately apparent that a spurious modulation was affecting the APT pictures, causing very noticeable sinusoidal displacements of the horizontal TV lines at a rate of approximately 33 cycles per picture frame. In addition, an intensity modulation of the lines, occurring at the same rate, caused alternately dark and light horizontal bars on the pictures. In spite of these effects, the image elements of the pictures, i.e., clouds and land masses, were quite easily identifiable. An investigation of this problem, and of possible means for alleviating its effects on the pictures, was immediately begun and the results are given in this report. The APT camera subsystem continued to produce useful, although distorted, pictures in this manner for a period of three months, after which a progressive loss of contrast gave evidence of vidicon degradation. After approximately five months of operation in orbit, the APT subsystem was no longer programmed because of the loss of contrast of the pictures.

Although the useful life of the APT subsystem was approximately five months, the camera was used over the two years of the evaluation to check out new APT sites around the world in preparation for the Nimbus I and the ESSA 2 launches.

The instrumentation and control subsystem performed satisfactorily throughout the evaluation period. The initial clock-setting accuracy of TIROS VIII was low (45-50 percent) but, by May, 1964, after several corrective measures had been taken at the ground stations, clock-setting accuracy had increased to 71.5 percent, and by April 1964, to over 85 percent. For the 2-year period covered by this report, the average clock-setting accuracy was approximately 85 percent.

The performance of the beacon and telemetry subsystem was normal until January 13, 1964. On that date, during a routine interrogation of the satellite on orbit 331, the telemetry readout from the low-frequency beacon transmitter (beacon No. 2) was interrupted when the associated telemetry commutator switch stopped at position 4 and would not advance. This failure was accompanied by an abnormally high current drain from the power supply and reduced satellite battery bus voltage. The high current drain ceased suddenly after a few orbits, and at the same time the battery voltage returned to normal. However, the channel No. 2 telemetry switch was permanently disabled and remained at position 4 for the remainder of the satellite's life. This failure did not prevent the reception of most of the telemetry data from the satellite since the redundant No. 1 telemetry channel continued to function normally. The operational tests and analyses performed in connection with this problem and the hypothesized cause of the problem are presented in detail in the section of this report covering the telemetry and tracking subsystem.

The reference-indicator subsystems (north indicator subsystem and attitude indicator subsystem) performed satisfactorily throughout the evaluation period. The APT rotation counter also performed satisfactorily, providing picture orientation data well within specified tolerances.

The overall performance of the satellite dynamics control subsystem was excellent. The de-spin mechanism performed very well, slowing the satellite from its initial spin rate of 128 rpm to an operational spin rate of 10.4 rpm (the design nominal value is 10 rpm and the limits are 8 and 12 rpm). The three firings of spin-up rockets on TIROS VIII produced spin-rate increases of 3.575, 3.52, and 3.37 rpm, all very close to the nominal value of 3.5 rpm.

The satellite's precession damper quickly reduced the nutation half-angle to within specified limits after satellite-booster separation and after satellite spin-ups. After approximately the first 1000 orbits the nutation angle of the TIROS VIII satellite exhibited an apparent tendency, previously unseen on the TIROS satellites, to fluctuate rather than to stabilize at a single value. However, the nutation angle remained small and within specified limits in spite of the apparent fluctuations.

Attitude prediction and control functions were performed with very good results throughout the period of this evaluation. Predictive accuracy was high, and the use of the magnetic attitude control (MAC) switch was very effective in spin-axis "steering" to obtain the desired solar-array input and picture coverage as well as in achieving suitable values for the residual dipole moment of the satellite to counteract the tendency of the satellite's attitude to "drift" in the earth's magnetic field.

The TIROS VIII satellite antennas performed normally in every respect. The ground stations experienced some temporary mechanical difficulties with the high-gain antennas at the Wallops Island and Alaska ground stations. These difficulties were quickly resolved and did not seriously impair the performance of either station.

The performance of the TIROS VIII power supply subsystem was excellent. The battery voltage remained well within the specified limits in all of the data examined except for the short span of several orbits beginning with orbit 331, during which the telemetry switch malfunctioned in such a way as to place an excessive load on the batteries. Immediately after the excessive load condition cleared itself (presumably by resulting in an open circuit) the power supply subsystem recovered and its performance returned to normal. The energy used by the satellite's subsystems never exceeded the energy available from the power supply subsystem except during the period of excessive current drain mentioned above.

The thermal response of the TIROS VIII satellite was generally in excellent agreement with predicted values. The only value which decreased below the predicted lower limit was that of the APT vidicon target temperature. An aluminized mylar cover for the protruding lens housing which had been installed to obtain a low emissivity characteristic and thus keep the vidicon target temperature above the specified lower limit, was evidently not effective or, with space exposure, lost its original characteristic.

The performance of the ground stations was generally satisfactory. Some operational difficulties were experienced when new ground-station personnel were assigned to the Wallops Island station. These difficulties decreased quickly as the new station personnel gained experience with the equipment and with the station operational procedures. Minor mechanical difficulties experienced at various times during the evaluation period by the ground stations were quickly remedied and did not seriously impair any station's operation.

The APT ground station installed at AED performed satisfactorily. This station was used to evaluate the performance of the APT camera subsystem and also to evaluate three different facsimile recorders for APT picture recording. Signal strengths received by the station were normally high and no fading was encountered. The AED station was used extensively in investigating the spurious modulation of the APT pictures previously noted.

Based on 200 pass summaries received by GSFC from 50 reporting APT stations up to January 31, 1964, the APT ground stations performed normally. One-third of the reporting stations considered the pictures usable, while most of the remaining stations gave no evaluation of picture usability.

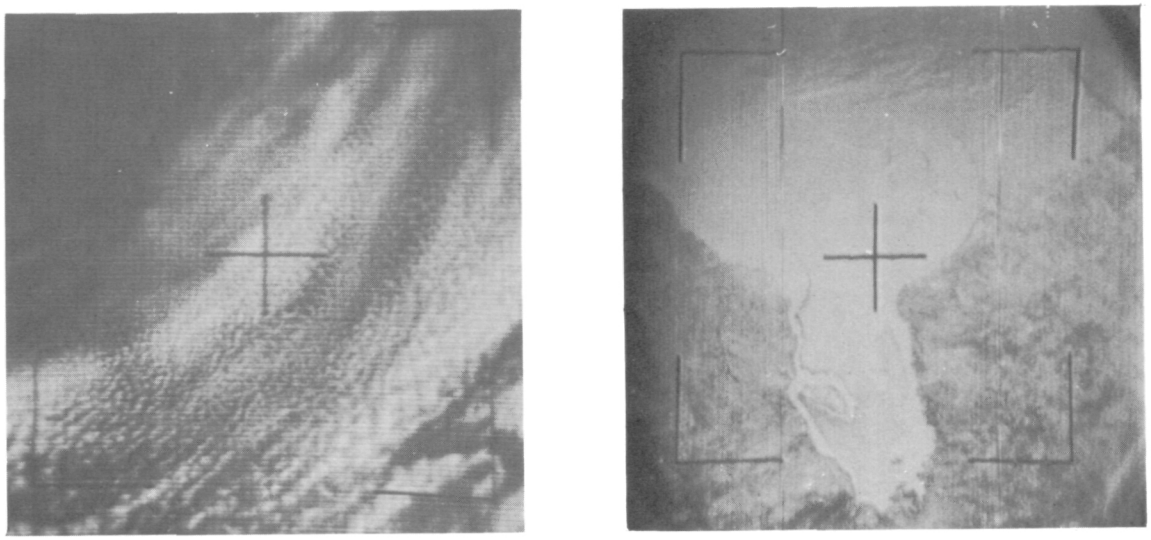
III. METEOROLOGICAL DATA COLLECTION

The TIROS VIII satellite produced over 89,000 meteorologically useful TV pictures from camera subsystem No. 1 (the standard TIROS camera subsystem) and 4,044 TV pictures from camera system No. 2 (the APT subsystem) in the 24-month period covered in this report. The APT pictures have not been classified with respect to meteorological usability as have the TIROS pictures because of the experimental nature of the APT system. The TIROS VIII meteorological data collection from both subsystems includes pictures of hurricanes, typhoons, tropical storms, and tropical depressions, as well as great numbers of pictures of the daily changing weather patterns of the earth and of the geographic features of the earth. The TIROS VIII collection includes pictures of the arctic and antarctic ice caps, ice formations in far northern estuaries, bays, and seas, snow conditions on high mountain ranges, high altitude jet streams, and other visible effects of the weather and climatic patterns of the earth.

This section of the TIROS VIII evaluation report presents a brief chronological history of the meteorological events recorded in the TIROS VIII TV photographs. A group of the TIROS VIII photographs is included as representative of those taken throughout the period of evaluation covered by this report. This material is not presented in an attempt to analyze the data from a meteorological standpoint, but only to provide a record of the more prominent meteorological events recorded by the satellite and, at the same time, to show typical picture quality over the period of evaluation and to illustrate the satellite's capability for imaging and recording the visible phenomena of the earth and its atmosphere.

Early pictures received from TIROS VIII, during December 1963, showed a cyclonic banding over the western Indian Ocean, and a vortex east of Madagascar. Other vortices were observed during early orbits in several parts of the Atlantic Ocean. Special weather bulletins were sent to Keyna, Africa, and Madagascar giving the location of the vortex east of Madagascar, and to the island of Mauritius giving the location of a second vortex in the western Indian Ocean. Many land marks were readily identifiable in these pictures, including India, Africa, Cyprus, Morocco, Arabia, Hispaniola, the Nile Delta, and Somali; many smaller bodies of water were also identifiable, including the Black Sea, the Great Salt Lake, Lake Tahoe, the Gulf of Oman, the Red Sea, the Niger River and the Gulf of Tehuantepec (Mexico). Examples of early-orbit pictures returned by TIROS VIII are shown in Figures III-1 and III-2.

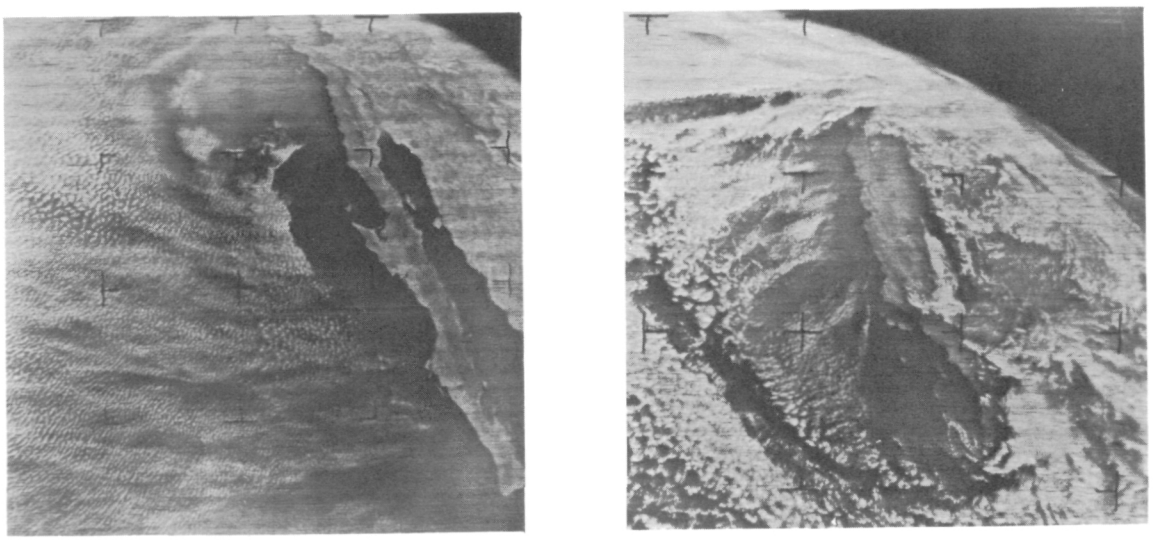
During January 1964, camera system No. 1 returned a total of 7,554 pictures of which 84.4 percent (6,337) were meteorologically useful. Two hundred and



a. Orbit 007, Direct Mode

b. Orbit 946, Remote Mode

Figure III-1. Early Orbit Pictures, Camera Subsystem No. 1 (TIROS)



a. Orbit 803

b. Orbit 832

Figure III-2. Early Orbit Pictures, Camera Subsystem No. 2 (APT)

eighteen nephanalyses were prepared and 18 special weather bulletins were issued from the data contained in the pictures. During this same period, system No. 2 (the APT camera system) was programmed to return a total of 948 pictures which were transmitted to APT ground stations throughout the world.

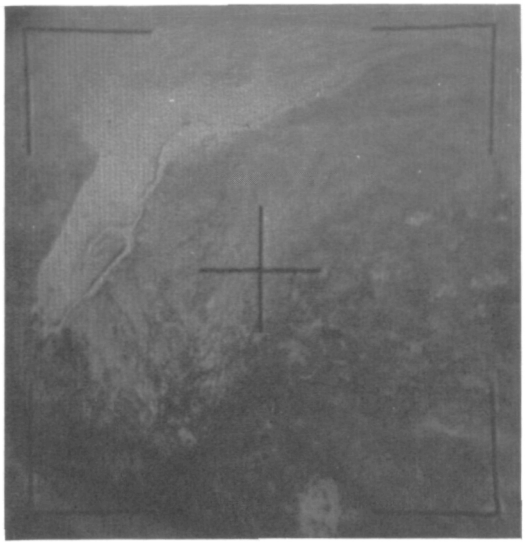
The photographic quality of pictures from camera No. 1 continued to be good to excellent throughout the first half of 1964; the APT camera system, however, beginning in April, returned pictures of progressively lower contrast until, in late May, programming was suspended because of very poor contrast.

From launch until June 30, the total number of pictures returned from camera system No. 1 was 32,805 of which 29,525 (90%) were meteorologically usable. From these pictures 1,134 nephanalyses were prepared and 76 weather bulletins and advisories issued. Camera system No. 2 in this same period, provided 4,044 pictures. Examples of TV pictures returned by the two camera systems during this period are shown in Figure III-3 and III-4.

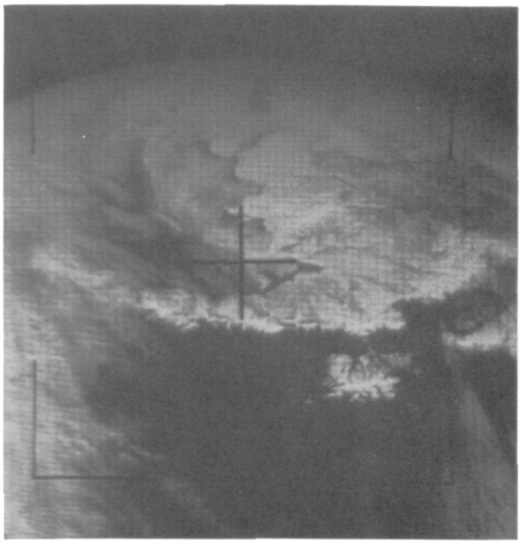
TIROS VIII made its earliest typhoon observation of the 1964 tropical storm season on July 7 when pictures of Typhoon Cora were taken approximately 600 miles east of the Philippine Islands on orbit 2882. On July 9, Typhoon Cora was again photographed, this time directly over the Philippine Islands on orbit 2911. Figure III-5 shows Typhoon Cora as it appeared on orbit 2911. Cora, much reduced in severity and reclassified as a Tropical Depression, was later photographed approximately 480 miles northwest of the Philippines.

Tropical Storm Doris was photographed over the Philippines on orbit 2939, on July 12, and again, approximately 300 miles east of the Philippines, on July 13, (orbits 2954 and 2968). By July 14, Doris had been reclassified as a typhoon and was observed by TIROS VIII on orbit 2983, approximately 180 miles northeast of the Philippines. Doris, reduced to tropical storm intensity, was observed on July 15 (orbit 2997) approximately 1,000 miles from the east coast of China. Doris on orbit 2983 is shown in Figure III-6.

TIROS VIII located Hurricane Odessa 750 miles west of Mexico on July 15, (orbit 3008) and tracked it on July 16 (orbit 3022), and July 18 (orbit 3051) to a position 850 miles southwest of Baja, California. Figure III-7 shows Odessa on July 16 (orbit 3022) southwest of Baja, California. Tropical Storm Elsie was observed 50 miles east of the Philippine Islands on July 16 (orbit 3011). On orbit 3079, July 20, TIROS VIII located Tropical Storm Prudence 750 miles southwest of Mexico (Figure III-8) and tracked it continuously to a point 200 miles southwest of California on July 26 (orbit 3137). Typhoon Flossie was observed by TIROS VIII on July 26 (orbit 3170) at a point 200 miles northeast of the Philippine Islands and tracked to within 120 miles of the east coast of China on July 29 (orbit 3199). Tropical Storm Grace was located July 26 (orbit 3169) about 1,000 miles east of Formosa on July 29 (orbit 3198). Typhoon Helen was photographed on July 31



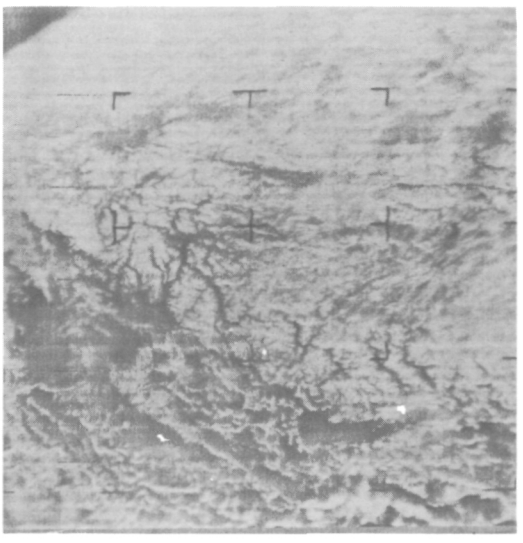
a. Orbit 1064, Remote Mode



b. Orbit 1195, Direct Mode

Figure III-3. Camera Subsystem No. 1 (TIROS) Pictures, Typical of First Half of 1964

a. Orbit 905



b. Orbit 1094

Figure III-4. Camera Subsystem No. 2 (APT) Pictures, Typical of Early 1964

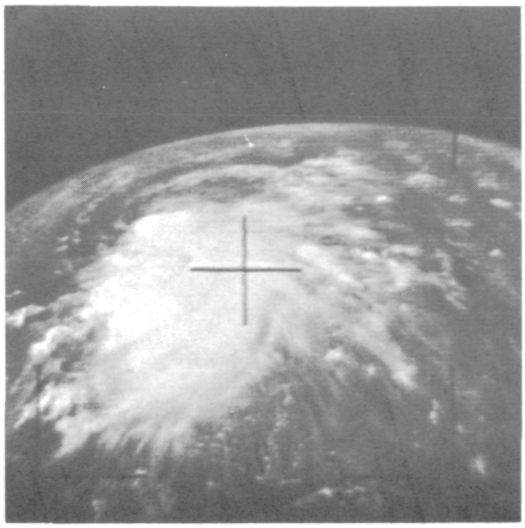


Figure III-5. Typhoon Cora, Over Philippines, Orbit 2911, July 9, 1964

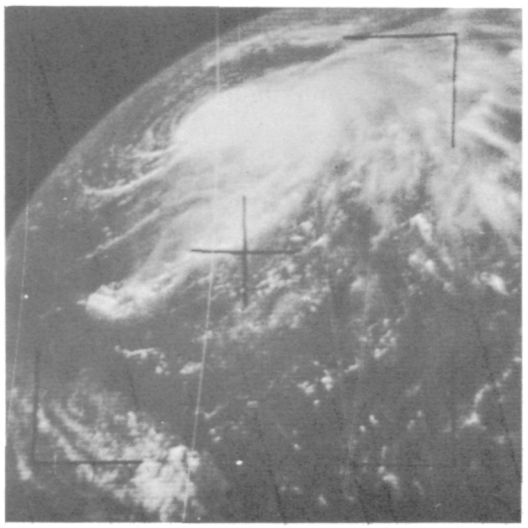


Figure III-6. Tropical Storm (Previously Typhoon) Doris, East China Sea, Orbit 2983, July 14, 1964

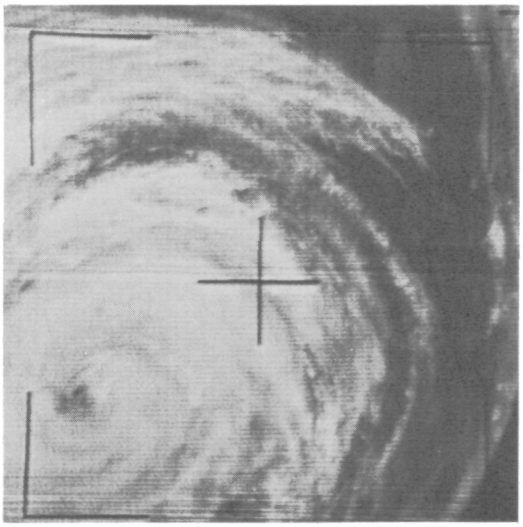


Figure III-7. Hurricane Odessa, Near Baja, California, Orbit 3022, July 16, 1964

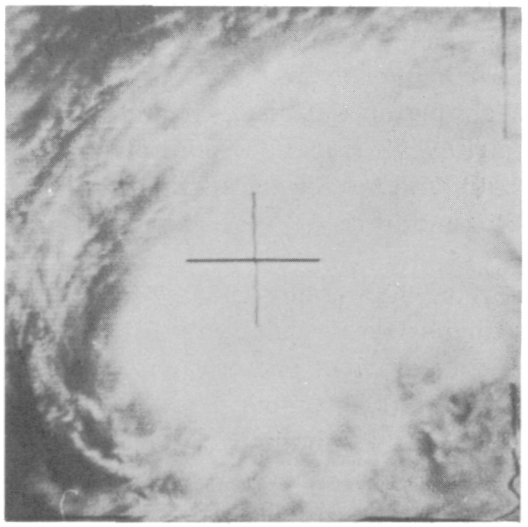


Figure III-8. Tropical Storm Prudence, West of Mexican Coast, Orbit 3079, July 20, 1964

(orbit 3241) 780 miles west of Baja, California, and continuously monitored on a zig-zag easterly course to a point about 200 miles off the California coast at Santa Maria on August 2 (orbit 3270).

In addition to Typhoon Helen, TIROS VIII monitored Tropical Depression Grace, Tropical Storms Brenda and Sylvia, and Hurricane Cleo during August 1964. Tropical Depression Grace was located over southern Japan on August 3 (orbit 3284). Tropical Storm Brenda was photographed 360 miles southeast of Bermuda on August 8. On August 10, Tropical Storm Brenda was photographed again, this time 600 miles southeast of Bermuda (orbit 3383). The edge of Tropical Storm June was photographed on August 10, and on August 11 (orbit 3390), the disturbed area associated with this storm was photographed off the east coast of the Philippine Islands.

Hurricane Cleo was first observed near the Lesser Antillies and monitored from August 22 through August 31 as it followed a northward path west of the Dominican Republic, over Haiti and Cuba (on August 24), to Key Largo, Florida on August 26 (orbit 3613). On orbit 3627, August 27, Hurricane Cleo was observed in the vicinity of Palm Beach, Florida. As it passed over Georgia, Cleo decreased in intensity and was reclassified as a Tropical Storm; it was observed over the Carolinas and Virginia on August 31.

Tropical Storm Sylvia was photographed by TIROS VIII approximately 180 miles west of Mexico on orbit 3571, August 24. During August, special weather bulletins were sent to the Air Force and the Navy regarding Typhoon Helen; to the Miami and San Juan weather bureaus and to the Air Force and the Navy regarding Tropical Depression Grace; to the Navy and to Miami regarding Tropical Storm Brenda; to the Air Force, the Global and Fleet Weather Centrals, the Washington National Airport and the Miami and San Juan Weather Bureaus regarding Hurricane Cleo; and to the Air Force, Global and Fleet Weather Centrals and the San Francisco and Honolulu Weather Bureaus regarding Tropical Storm Sylvia.

During September 1964, TIROS VIII photographed Hurricane Cleo, Tropical Storms Dora, Anita, and Billie and Typhoons Ruby and Wilda. Tropical Storm Dora was first photographed by TIROS VIII at a point 500 miles east of the West Indies on September 1 (orbit 3698). By September 2, Tropical Storm Dora had intensified to hurricane force and was characterized by tight banding, 4 degrees in diameter. It was photographed on a northwesterly course 800 miles northeast of Puerto Rico (Figure III-9). On September 3, Hurricane Dora had moved to within 460 miles of Puerto Rico and was observed on September 4 and 5 while it moved to a point 900 miles east of Florida. Tropical Storm Cleo, observed by TIROS VIII on September 1, increased to hurricane intensity on September 2 and was photographed on orbit 3712 in the vicinity of Cape Hatteras. Cleo was last observed on September 3 (orbit 3726) near Cape Hatteras.

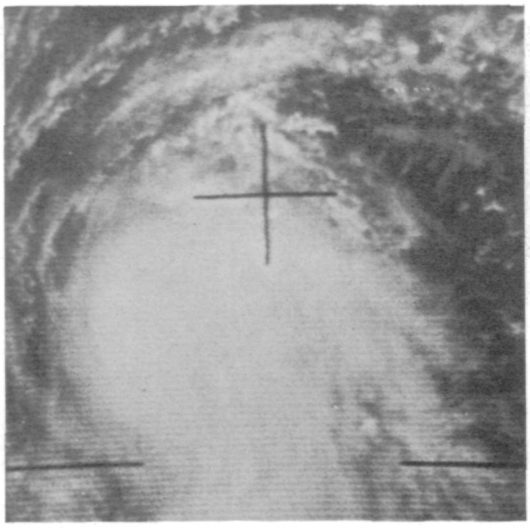


Figure III-9. Hurricane Dora, Northeast of Puerto Rico, Orbit 3712, September 2, 1964

On September 4, Typhoon Ruby (Figure III-10) was observed by TIROS VIII on orbit 3734 approximately 300 miles northwest of Hong Kong, China. On September 6 the southern edge of Tropical Storm Ethyl was observed approximately 1,800 miles east of Florida (orbit 3769). TIROS VIII observed Typhoon Wilda on September 21 at a point 840 miles east of the Philippine Islands on orbit 3984 and tracked Wilda on a northwesterly course. On September 22, Wilda was observed 900 miles east of Formosa (orbit 3999) and, two days later, over southern Japan. Typhoon Wilda on orbit 4028 is shown in Figure III-11. Tropical Storm Billie was observed 30 miles east of the Island of Samar in the Philippines on September 28.

During September, special bulletins were sent to the Global and Fleet Weather Centrals and to the Miami and San Juan Weather Bureaus regarding Hurricane Dora; to the Air Force, Global and Fleet Weather Centrals and the Miami and San Juan Weather Bureaus regarding Typhoon Ruby; to the Pacific Air Command and Global and Fleet Weather Centrals regarding Typhoon Wilda; and to Global Weather Central, the Navy, and the Pacific Air Command regarding Tropical Storm Billie.

From October 1 until December 20, 1964, TIROS VIII observed Hurricane Hilda and Isabel (Figure III-12); Typhoon Opal; and Tropical Storms Clara (later Typhoon, then Tropical Depression), Ellen, Fran and Norma.

Hurricane Hilda was observed on October 1, 2, and 4 as it progressed from a position 300 miles south of Louisiana to the Gulf of Mexico just off the coast of Louisiana. Tropical Storm Clara was observed from 300 miles west of the

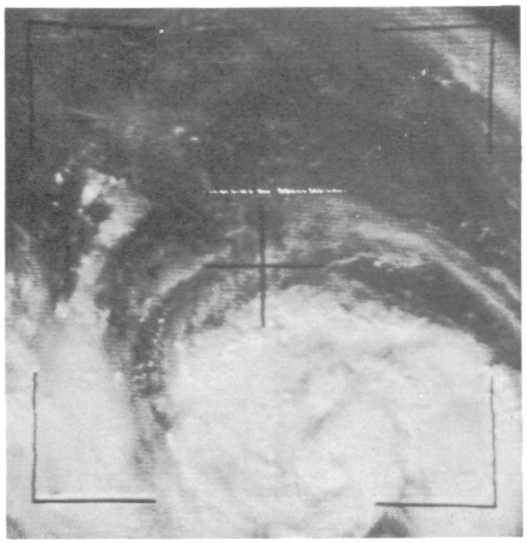


Figure III-10. Typhoon Ruby, Over China, Orbit 3734, September 4, 1964

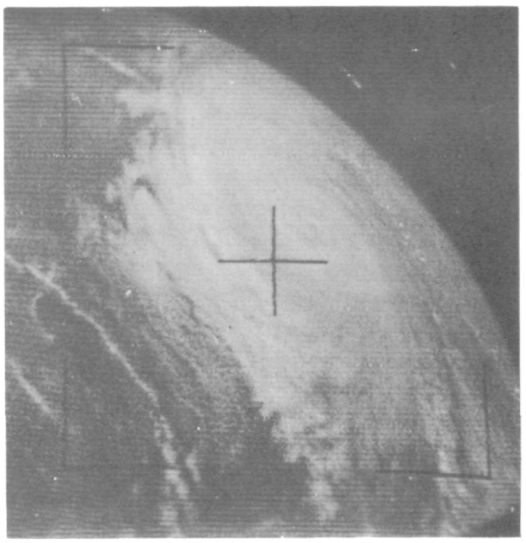


Figure III-11. Typhoon Wilda, East of Formosa, Orbit 4028, September 24, 1964

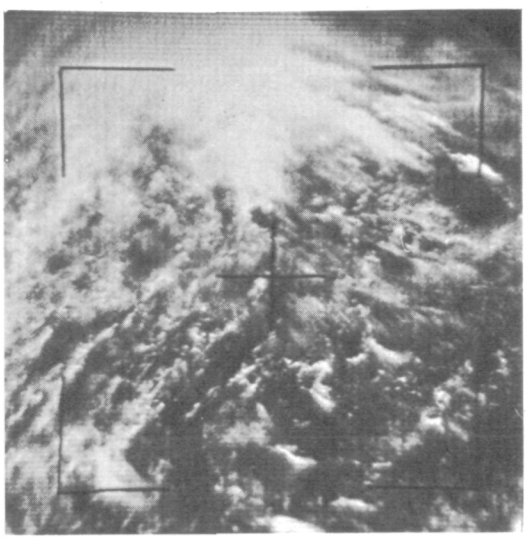


Figure III-12. Hurricane Isabel, Orbit 4337, October 15, 1964

Philippine Islands on October 3 and 4 to a position over the Philippines on October 5. On October 6, Clara had intensified to a typhoon and was observed 300 miles west of the Philippines. By October 7, Typhoon Clara had traveled to a point 120 miles south of Hainan, China. On October 9, Clara had decreased to tropical depression intensity and was observed over Laos. On October 8, Tropical Storm Dot was observed 60 miles east of the Catanduanes Islands in the Philippines. On October 9, Dot, increased in intensity and reclassified as a typhoon, was observed at a point 120 miles northwest of the Philippines. Typhoon Dot was last observed over the south coast of China on October 10. Tropical Storm Ellen was photographed by TIROS VIII on October 9 near Kwajalein on orbit 4256. On October 15, TIROS VIII located Tropical Storm Fran 600 miles southwest of Wake Island and Hurricane Isabel just off the coast of the state of Georgia. On November 25, TIROS VIII located the southern portion of Tropical Storm Nora over northern Borneo and the Sulu Sea. On December 9, 11, and 13, Typhoon Opal was photographed in the North Pacific Ocean, northeast of the Christmas Islands.

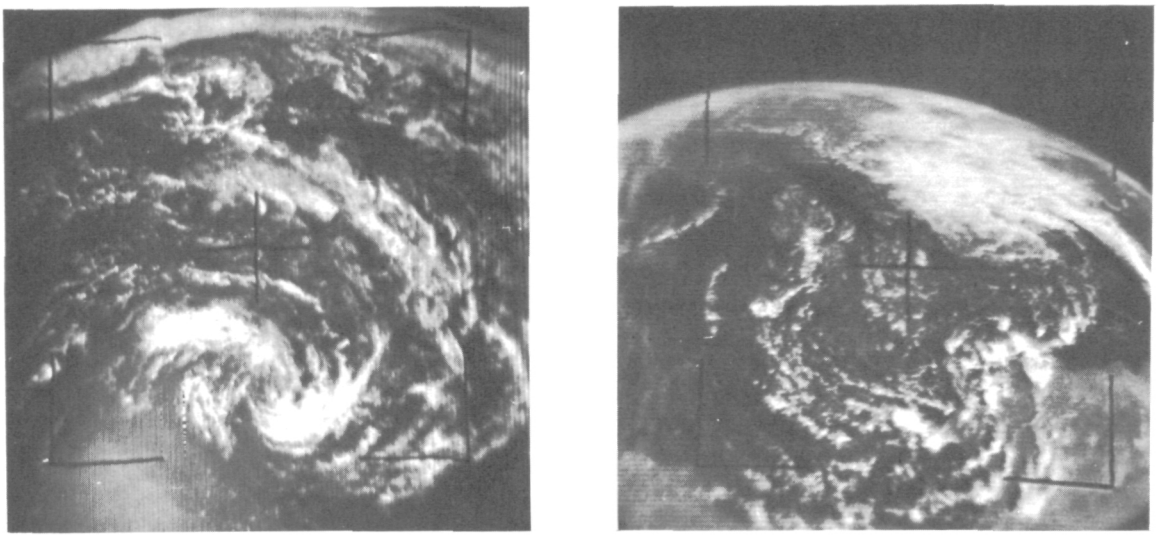
During the latter half of December 1964, the TIROS VIII subsystems continued to function normally except for the APT camera subsystem, which was operable but unable to produce video, and the side No. 2 telemetry commutator, which was inoperable. Programming of camera subsystem No. 1 continued at a normal rate of up to seven camera sequences per day. The problem of partial and missing frames was not encountered, having been overcome by higher satellite temperatures obtained with corrective attitude programming.

Accuracy of setting the satellite's camera clocks was good (85 percent precisely accurate out of the total programmed in December). The clock-setting problem experienced earlier in TIROS VIII operation had been largely overcome by the use of a new command format and improved ground station equipment operation.

Normal operation continued during January. Programming was reduced during the early part of January because of low solar illumination in the picture areas and suspended on January 21 when the beacons were turned off to avoid any possible conflict with the TIROS IX launch operations.

Programming was resumed during February but suspended for brief periods when any possibility of conflict with TIROS IX operations existed. The average programming rate during February was three sequences per day. On February 8, a pair of spin-up rockets was fired, increasing the spin rate from 8.26 to 11.78 rpm. The amount of increase, 3.52 rpm, was very close to the nominal value of 3.5 rpm.

During March, the average programming rate was three picture sequences per day. From March 19 through March 23, TIROS VIII was programmed in support of the Gemini project. Two camera No. 1 remote photographs taken during March are shown in Figure III-13.



a. Orbit 6449, Camera 1, Remote

b. Orbit 6616, Camera 1, Remote

Figure III-13. TIROS VIII Pictures Taken During March, 1965

TIROS VIII was programmed at an average rate of four orbits per day during April. Picture quality continued to be good as did clock-setting accuracy (85 percent on-time clock alarms). While TIROS IX was undergoing an attitude maneuver, TIROS VIII provided the cloud pictures for routine meteorological analysis.

During May, the programming rate was increased slightly to 4.5 orbits per day and picture quality remained good. (See Figure III-14.) The TIROS VIII pictures continued to be used for routine meteorological analysis in place of TIROS IX pictures. A maximum gamma angle (75 degrees) was reached on May 12. The low temperatures experienced at this time resulted in some incomplete TV pictures. Between May 4 and 14, the satellite was exposed to 100 percent suntime; low solar elevation angles along the picture-center track occurred during the same period and camera programming was reduced. The APT camera subsystem was programmed on orbit 7378 by the Gilmore Creek, Alaska ground station and 5 APT frames were read out, 2 of which were partial. As previously, the TV carrier wave was received but was unmodulated.

Picture programming continued at an average rate of 4.5 sequences per day in early June but was reduced after June 19 to prevent conflicts with TIROS X prelaunch exercises. Picture quality remained good (Figure III-15) as did clock performance (82 percent on-time alarms). Some tape wear was evident in the remote pictures. The 18-month timers, scheduled to operate in June, did not operate and the beacon transmitters continued to transmit.

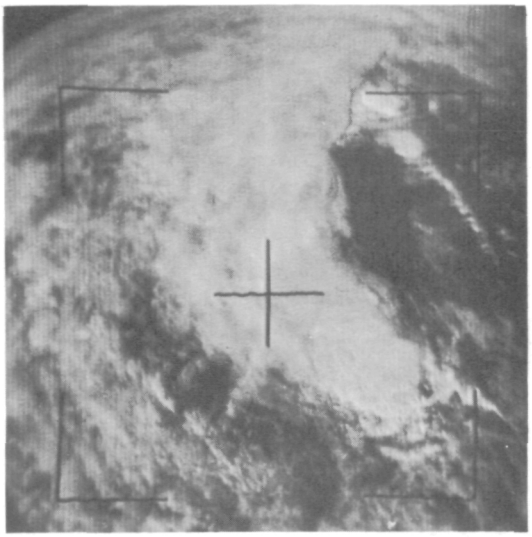


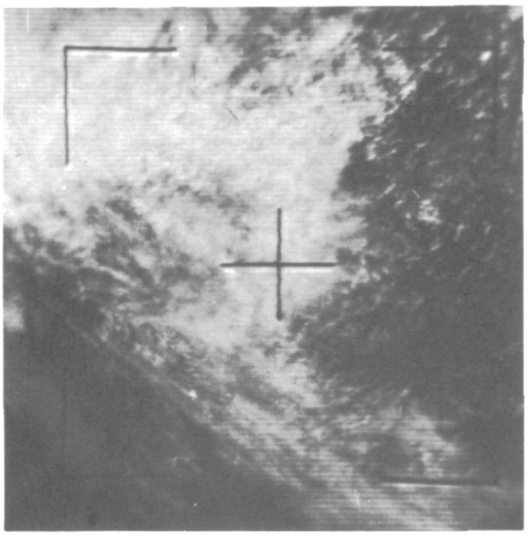
Figure III-14. Orbit 7221, Camera 1, Remote Picture Taken During May, 1965

On July 1, the beacon transmitters were turned off temporarily (BEACON KILL) to prevent interference with the TIROS X launch on that date. The beacons were restored to operation on July 6 and the satellite was programmed for picture taking at an average rate of two orbits per day. Only direct sequences were programmed during this period and the beacons were turned off at the end of each sequence to prevent interference with TIROS X operation.

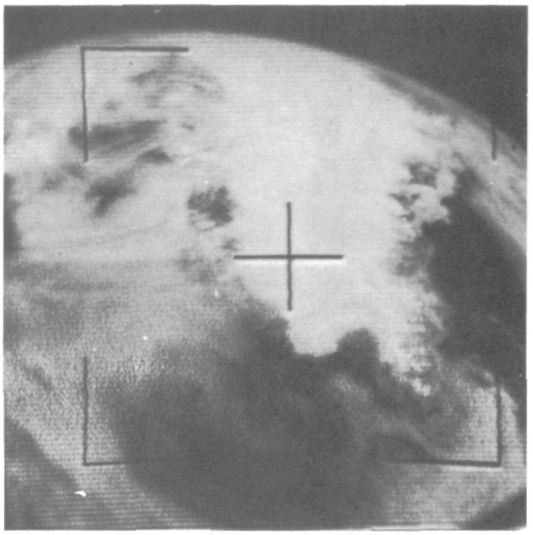
TIROS VIII was programmed to provide picture coverage over the mid-Pacific and mid-Atlantic recovery areas in support of the Gemini 5 flight beginning on August 19 and continuing through August 29. Picture quality (Figure III-16) and clock-set operation remained good.

During September, TIROS VIII participated in the tropical storm watch, photographing Typhoon Rose on one occasion and Hurricane Betsy (Figure III-17) on numerous occasions. Picture quality remained good and the camera was programmed at an average rate of four sequences per day. Clock setting accuracy was 80 percent. On orbit 9382 the APT camera was programmed and returned three picture frames, all blank, as before.

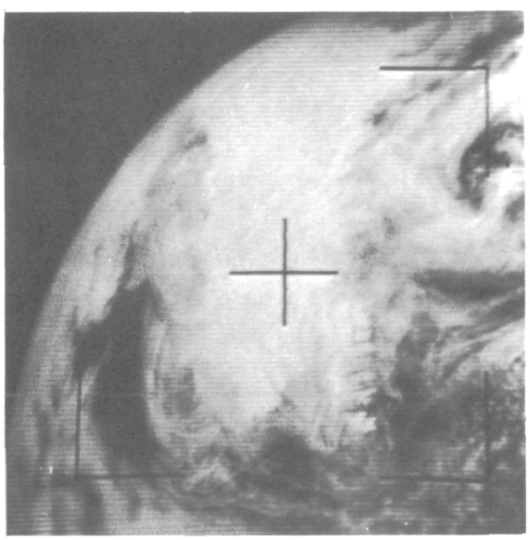
APT picture sequences were again programmed during October. Altogether, five APT sequences were programmed between October 18 and 23. Again, no video modulation was received but the operation of the camera electronics and transmitter continued to be normal. The average programming rate of the TIROS camera subsystem during October was 3.9 sequences per day. Picture quality was fair to good with some evidence of a decline in picture quality. However, the pictures continued to be of usable quality as shown in Figure III-18.



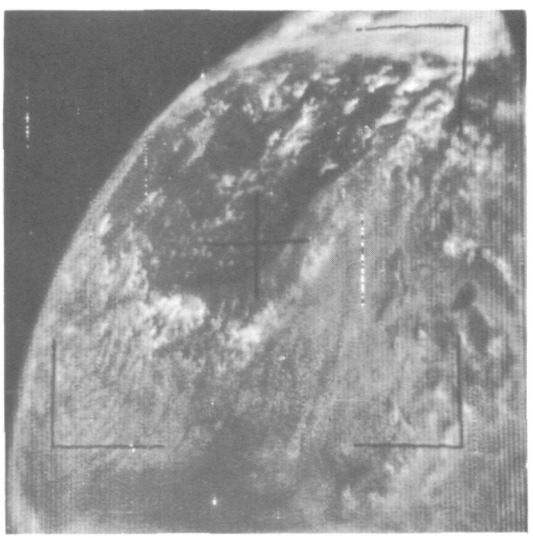
a. Orbit 7766, Camera 1, Remote



b. Orbit 7995, Camera 1, Remote



c. Orbit 8036, Camera 1, Remote



d. Orbit 8067, Camera 1, Remote

Figure III-15. TIROS VIII Photos Taken During June, 1965

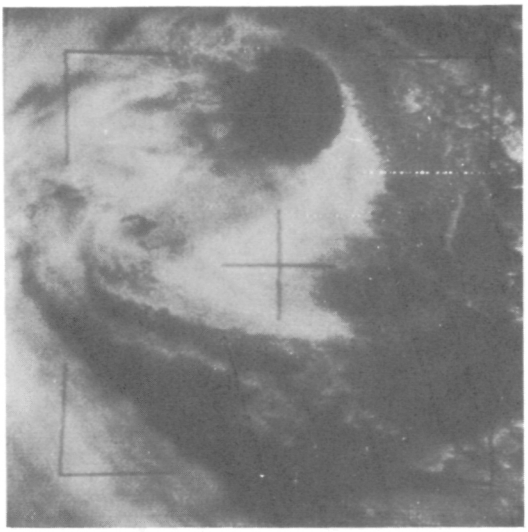


Figure III-16. Orbit 8694, Camera 1, Remote; Funneling Circulation Center Observed During August 1965

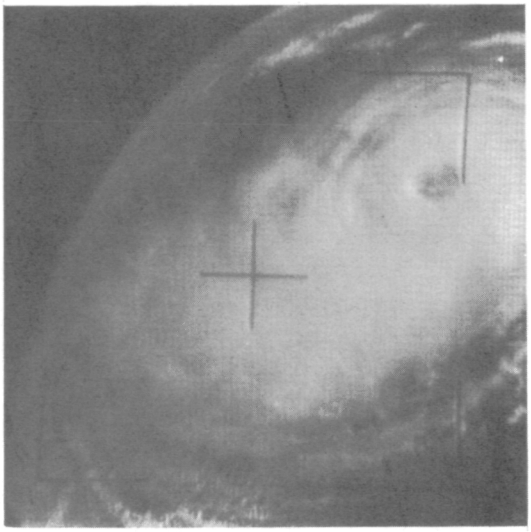


Figure III-17. Orbit 9067, Camera 1, Direct; Hurricane Betsey Observed on September 6, 1965

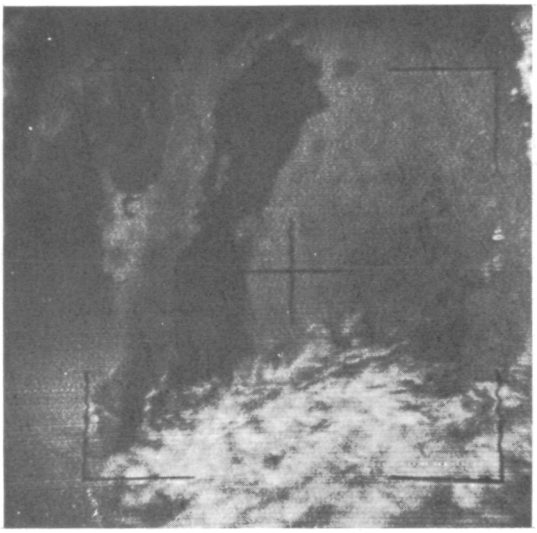
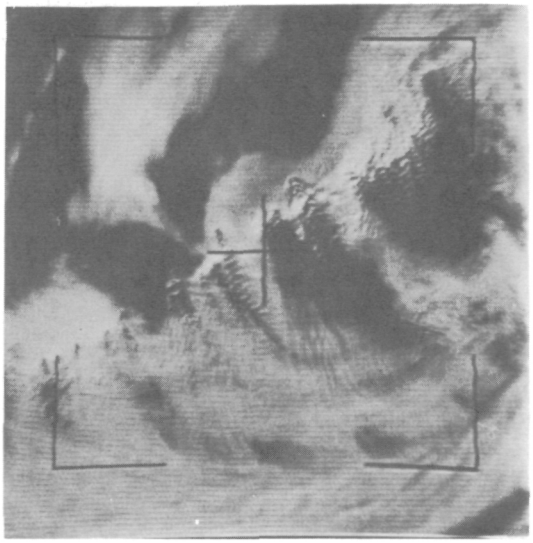
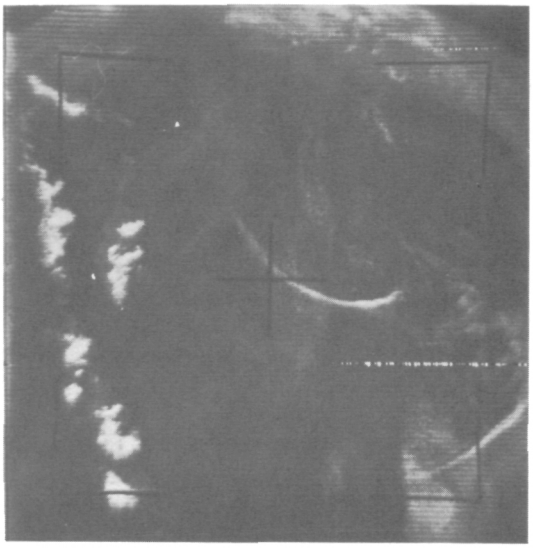


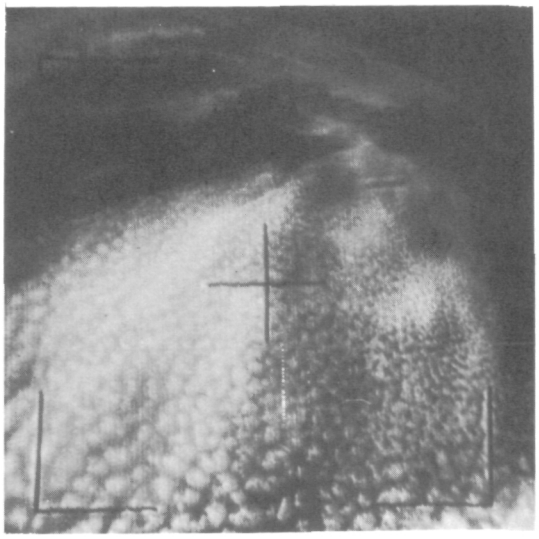
Figure III-18. Orbit 9965, Camera 1, Remote; Baja, California, Observed in Late October 1965



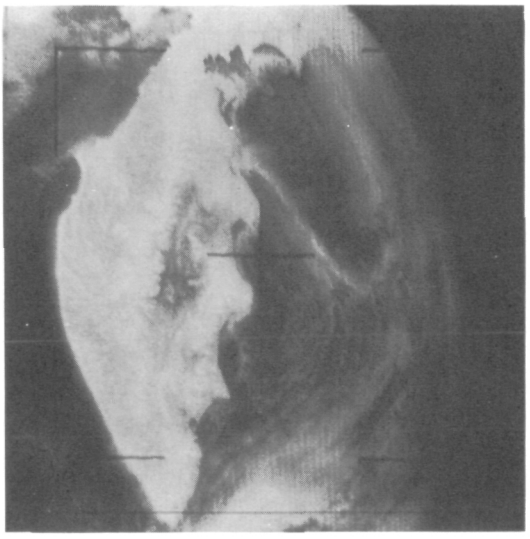
a. Orbit 3326, Camera Subsystem No. 1



b. Orbit 4013, Camera Subsystem No. 1



c. Orbit 6456, Camera Subsystem No. 1



d. Orbit 6827, Camera Subsystem No. 1

Figure III-19. Variety of Cloud Structures Recorded by TIROS VIII

The third spin-up of TIROS VIII took place on orbit 10,026. The spin up, commanded by the Alaska ground station, increased the spin rate from 8.16 to 11.53 rpm, an increase of 3.37 rpm (as compared with the 3.5 rpm nominal value) after one year and 11 months in the orbit environment. At the beginning of the month, the satellite was programmed at a rate of 5.75 picture sequences per day. Later, on November 19, programming was suspended as the satellite went through a period of low solar illumination of the picture centers. The quality of the TV pictures showed a further decline and was rated as fair to good. Performance of the satellite subsystems was carefully observed for evidence of failure trends.

On December 21, 1965, TIROS VIII achieved its second anniversary of operation in orbit. During December, the satellite was programmed in support of the Gemini 6 and Gemini 7 missions. The average picture programming rate was four sequences per day and clock setting accuracy was good at 86.5 percent. Picture quality had declined but the pictures were still rated as usable. By the end of the month TIROS VIII had taken a lifetime total of 97,156 pictures with camera subsystem No. 1, 89,963 of which were meteorologically useful.

* * * * * *

A group of TIROS VIII cloud photographs, taken during the evaluation period covered in this report, and showing the capability of the cameras for resolving various types of cloud constructions, is presented in Figure III-19.

IV. SYSTEM DESIGN

TIROS VIII was the fourth of the Series II TIROS spacecraft, and the fifth, and last, spacecraft to be qualified and delivered for launch under Contract No. NAS 5-1335. It was the first satellite to include an Automatic Picture Transmission (APT) subsystem.

Under the original terms of the contract, this spacecraft was designated as a standard TIROS spacecraft, employing two standard TIROS television cameras similar in design to TIROS VII. However, in October 1962, NASA directed AED to study the feasibility of replacing one of the spacecraft's two standard TIROS TV camera subsystems with the APT camera subsystem. Based on the results of this feasibility study, NASA gave instructions to AED, in February 1963, to modify the spacecraft to include a government-furnished APT subsystem and to remove the government-furnished infrared (IR) equipment, originally included in the design.

The revisions in the design of the TIROS VIII spacecraft had little effect on its external appearance, which remained nearly identical to that of the previous TIROS spacecraft. An external view of TIROS VIII is shown in Figure IV-1. Approximately cylindrical in shape, the spacecraft had a diameter of 42 inches and a height (not including antennas) of 22.5 inches. With all components mounted, it weighed 300.26 pounds. The spacecraft was an assembly of a circular baseplate, on which most of the components were mounted, and a hollow cover or "hat" which was fitted over the components and attached to the circumference of the baseplate. The underside of the baseplate was reinforced by radial and inter-costal ribs. A four-element, crossed-dipole antenna array was attached beneath the baseplate. A single-element "whip" antenna was mounted on the top surface of the hat, on the line of the satellite's spin axis. The two television cameras projected through the baseplate with their optical axes parallel to the spin axis.

The lateral surface of the spacecraft consisted of 18 flat, rectangular panels mounted on a framework. Solar cells covered most of the top and side surfaces of the hat to convert solar energy to electrical energy in order to supply the satellite's power requirements. Altogether, 9120 solar cells were mounted on the exterior of the spacecraft, grouped in "shingles" of 5 cells each. Approximately one-half of these cells were of "gridded" construction, to provide higher conversion efficiency than standard solar cells.

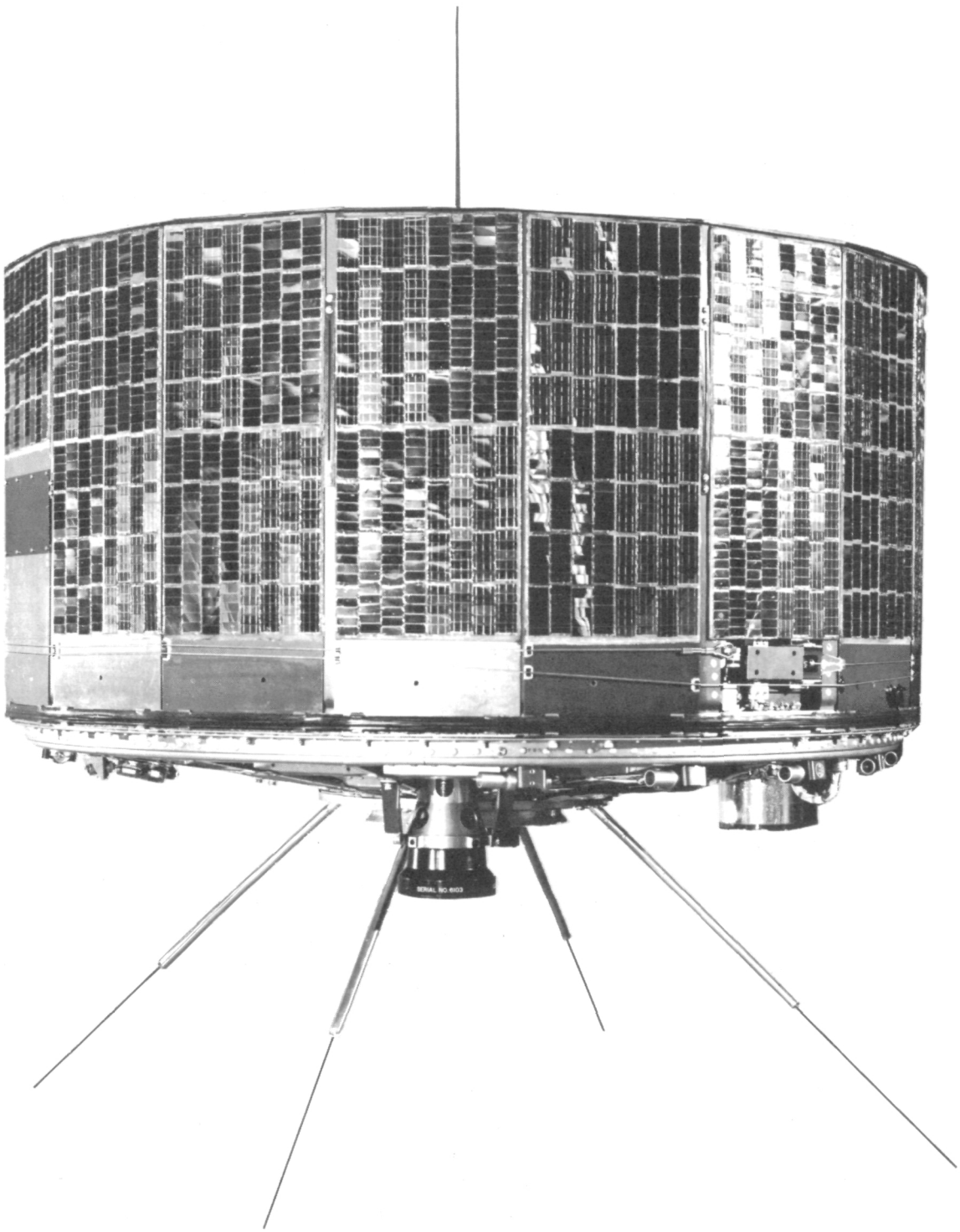


Figure IV-1. TIROS VIII Spacecraft

The meteorological information-gathering devices on TIROS VIII consisted of a standard TIROS wide-angle TV camera subsystem (camera subsystem No. 1) and an Automatic-Picture-Transmission (APT) subsystem (camera subsystem No. 2). Camera subsystem No. 1 consisted of (1) a 500-line, one-half inch, vidicon TV camera, (2) a camera electronics unit, (3) a magnetic video-tape recorder transport, (4) tape recorder electronics (in the same package with the tape transport), and (5) a TV transmitter. The TV camera was provided with an f/1.5, Elgeet Navitar wide-angle optical lens having a focal length of 5 millimeters and a view angle of 104 degrees (diagonal). At the mean satellite altitude of approximately 450 statute miles, the lens provided an image on the vidicon faceplate of an earth area of approximately 500,000 square miles. This image was scanned at a horizontal rate of 250 lines per second and a vertical rate of 0.5 frames per second to produce one complete 500-line frame in the 2-second readout period. Scanning the square image area at a rate of 250 lines per second produced a video spectrum extending from d-c to a maximum of 62.5 kc (250 lines per second x 250 picture elements per line).

Camera subsystem No. 1 could be programmed for either direct, remote, or playback operation. When the satellite was within range of a CDA station, the direct mode of operation was used for real-time picture transmission. In this mode, the video generated by camera No. 1, after frequency modulation on a subcarrier, was applied directly to TV transmitter No. 1 for real-time transmission to the interrogating ground station so that it appeared, line-for-line on the ground station monitor, as it was being generated by the satellite camera. The direct mode could be maintained as long as the command tone for a direct-camera sequence was received by the satellite. This period varied depending on the satellite's elevation above the horizon with respect to the ground station. The remote mode of operation was utilized when the satellite was to take pictures out of range of a CDA station. For this mode, a command program was transmitted to and stored in the satellite and the camera subsystem was automatically turned on and operated at a pre-set time contained in the command program. A remote sequence consisted of 32 pictures; the video information obtained during a remote sequence was stored by means of the magnetic-tape recorder for later transmission to a ground station. The playback mode of operation was used to recover the pictures stored during remote operation of the camera subsystem. Playback operation was commanded while the satellite was within communications range of a CDA station and the video data obtained and stored in the previous remote sequence (along with associated attitude data) was transmitted back to the interrogating ground station. While the subsystem was in the playback mode, and transmitting recorded picture data to a ground station, the necessary command program for taking remote pictures during the next orbit could be transmitted to the satellite. The programming of remote pictures entailed prior calculations of the portions of the earth that would be sufficiently illuminated for picture taking, of the portion of the orbit where the camera view

angle of the earth (determined by satellite altitude) would be suitable for picture taking, and of the amount of satellite electrical power that would be available for camera operation during the orbit (based on predicted solar illumination of the satellite's solar cell array).

In both modes of operation, the camera subsystem No. 1 video signal was frequency-modulated on an 85-kc subcarrier. The lower sideband produced by this modulation was within the optimum frequency response of the tape recorder. During direct picture taking or playback operation the video subcarrier was frequency-modulated on the 235-Mc carrier of the TV transmitter for transmission to the ground station.

Camera subsystem No. 2, the APT subsystem, consisted of (1) a high-persistency, slow-scan, 1-inch vidicon, (2) a camera electronics module, (3) a narrow-band, 5-watt, 136.95-Mc FM video transmitter, (4) a telemetry conditioner, and (5) associated decoding, timing, computing, and control circuits. This subsystem utilized a wide-angle, 104 degree, f/1.8, Kinoptic Tegea lens with a focal length of 5.7 millimeters. Assuming a zero nadir angle of the camera optical axis, each APT picture would encompass a square ground area approximately 850 statute miles on a side, and would provide an effective resolution of approximately 1.2 miles of ground distance per TV line.

Camera subsystem No. 2 could be operated in the direct or the remote mode of operation. The direct mode was employed while the satellite was within command communications range of a CDA ground station and provided immediate picture transmission to all APT ground stations within range of the satellite's APT transmitter at the time the picture command was being transmitted from the CDA station to the satellite. The remote mode, like that of camera subsystem No. 1, involved the use of a command program, transmitted by the CDA station and stored by the satellite, which delayed and then initiated picture taking at a later point in the orbit where scene illumination, camera nadir angle, and the presence of suitable receiving stations made picture taking desirable. However, unlike the remote operation of camera subsystem No. 1, the picture data obtained remotely by subsystem No. 2 was not recorded, but was transmitted as it was being generated, for immediate reception by those APT stations that were within range of the satellite at that time in the orbit.

In either mode of operation, camera subsystem No. 2 pictures were taken at intervals of approximately 215-seconds and the video data was transmitted directly to the ground and received by any APT ground station within range of the satellite's APT transmitter. In the remote mode, camera subsystem No. 2 performed eight picture-readout cycles. The first cycle was used for equipment warm-up and did not produce a full picture. The total number of useful pictures available from a remote sequence was, therefore, counted as seven.

The narrow-band transmission from the APT camera subsystem allowed the use of relatively simple, inexpensive receiving equipment that was obtained, operated, and maintained by government and private organizations in nations throughout the world. With this equipment, the APT stations received local, real-time, cloud-cover information each time the satellite passed within range of their stations with its APT equipment active during daylight hours.

Each transmission of TV data from camera subsystem No. 1, the TIROS camera subsystem, in either mode of operation was accompanied by picture-orientation (sun-angle) data. This data was produced by a set of nine sun sensors spaced around the periphery of the satellite hat at 40-degree intervals. The sensors generated pulses coded by width, as the satellite rotated, providing data from which direction of the sun from the satellite at the time each picture was taken could be derived. At the nominal satellite spin-rate range of 8-to-10 rpm, two or three pulses were generated in the two-second camera readout period. This was sufficient data to determine, from the pulse-width coding, the azimuth of the sun from the center of the satellite in the plane of the baseplate. Using this data in conjunction with ephereris data, the sun direction in each TV picture was calculated.

The sun-angle pulses were modulated on a 10-kc subcarrier, which was recorded on a separate track on the video tape during remote operation or combined with the TV subcarrier for direct transmission to the ground station during direct camera operation. One of the sun sensors in the north-indicator subsystem (the sensor at the 220-degree baseplate radial location) was also utilized by camera subsystem No. 2, to initiate camera shutter operation. The start of an APT picture-taking cycle was inhibited until this pulse was received in order to establish a sun direction in the APT pictures that could be readily calculated. The angle between the sun-sensor axis and the view axis of the APT camera was permanently set prior to launch so that the sun direction (and from that the geographical directions) in the pictures could be determined without the requirement for complex equipment or procedures.

The TIROS VIII instrumentation control subsystem consisted of the programming, communications, and control components necessary to provide control of the satellite operations by the CDA stations. The control functions included the various modes of TV camera operation, operation of satellite dynamics devices (spin rate, attitude, nutation, control of telemetry read-out, and control of the satellite's beacon transmitters. The ground station portion of this subsystem included programming equipment for the automatic generation and transmission of preset commands to the satellite during a contact. The satellite portion of the subsystem received, demodulated, and distributed the commands to the individual control circuits in the satellite.

The satellite contained two 50-milliwatt beacon transmitters, one operating at 136.23 Mc and the other at 136.92 Mc. The beacons operated continuously during normal satellite operation, providing tracking signals to the CDA stations and to tracking stations. Provisions were made to turn off the beacons as an emergency measure (e.g., to conserve power) and to reactivate them at a later time. TIROS VIII, like TIROS VI and VII, also carried timing devices to turn off both beacons permanently after a predetermined time. The timers on TIVOS VI and VII were set to turn the beacons off after one-year's operation; on TIROS VIII, the timers were set for an operating period of one and one-half years.

At the start of each satellite-to-ground contact, forty-eight of the satellite's most significant operating parameters and six calibration voltages were sampled and telemetered to the ground station by modulation of the beacon transmitters. Twenty-two of the parameters were transmitted by both beacons. The remainder were divided between the two beacons. When the beacon transmitters were not modulated by telemetry data, they were modulated by attitude-indicator data (horizon pulses) by means of which the satellite's attitude could be measured.

The Minitrack Network stations tracked the beacon signals to obtain satellite ephemeris data. These stations recorded and relayed attitude-indicator and ephemeris data to the TIROS Technical Control Center (TTCC). TTCC used the data to predict satellite orbit tracks for use by the ground stations in acquisition and tracking, and to predict satellite attitude, power availability, ground track illumination and other information on which the command programs for later orbits were based.

Four devices for controlling satellite dynamics were included on the satellite; a precession damper, a de-spin mechanism, five pairs of spin-up rockets, and a magnetic attitude-control device. All of these devices were fundamentally similar to their counterparts on the TIROS VII satellite.

The satellite's operational spin rate of 8 to 12 rpm was dictated by a minimum value, below which gyroscopic stabilization of the spin axis would begin to lose effectiveness, and a maximum value above which picture smear would occur. Satellite spin-down from the orbit-injection spin rate of 126 rpm required for stabilization of the third-stage rocket to the satellite operational spin rate was achieved by activation of the de-spin mechanism. This mechanism automatically released a pair of spin-reducing weights four to seven minutes after the satellite had separated from the third-stage rocket. Spin-down from the high initial rate to the operational rate was accomplished in approximately 0.5 seconds. The prelaunch adjustment of the de-spin mechanism differed from that of the previous satellites in that the cables used in this mechanism were adjusted for a specific tension since cable tension had been shown to materially influence the de-spin ratio.

The precession dampers were uncaged after the separation of the satellite from the third-stage rocket to dampen any "wobble" caused by precession or nutation. The precession dampers quickly reduced any wobble that accompanied the initial de-spin or the later satellite spin-ups.

Five pairs of spin-up rockets were installed about the periphery of the baseplate and wired for firing by pairs on ground command. The firing of these rocket pairs increased the satellite spin rate by a nominal amount of 3.5 rpm per pair after it had been reduced below the required minimum value of 8 rpm by interaction of the satellite's magnetic dipole with the earth's magnetic field.

The satellite's attitude was varied as necessary in order to overcome the natural precession resulting from spinning and orbiting in the earth's magnetic field and in order to achieve favorable satellite attitudes for camera pointing, scene illumination, and solar input. The device used for attitude control consisted of a 250-turn coil of wire, wound about the periphery of the satellite, and a 12-position switch that controlled the magnitude and direction of d-c current through the coil. In this manner, the strength and polarity of the satellite's magnetic dipole could be controlled by ground command. This control could move the spin axis a maximum of 15 degrees per day utilizing the torque produced by interaction between the satellite's magnetic field and the magnetic field of the earth.

Electrical energy for operation of the satellite's electronic circuits was provided by a subsystem that included the solar-cell array and storage batteries. During the "daylight" portion of the orbit, the solar array supplied the satellite's energy needs and maintained the batteries at full charge. During the "night-time" portion of the orbit, the batteries supplied electrical power to the satellite's subsystems.

The TIROS VIII ground complex consisted of three primary Command and Data Acquisition (CDA) stations, a back-up CDA station, selected stations of NASA's Minitrack Network, and approximately 45 APT ground stations. One of the Minitrack stations, located at Santiago, Chile, was provided with a limited command (clock-start) capability to extend the remote picture-taking capability of the satellite to orbits on which it was out of contact with any CDA station. Programming the satellite for a remote picture sequence consisted of two fundamental operations. The first was to set the satellite's "clock" circuits for a specific delay period before picture taking would start. The second was to start the clocks. Only the CDA stations possessed the equipment to set the clocks. However, Santiago, with its "clock-start" capability could start a clock that had been set by a CDA station. This capability made it possible to greatly extend the total available delay period and thereby to obtain pictures from some orbits that would otherwise have been inaccessible to the CDA stations. The locations and the operations of various Minitrack Network stations in contact with the satellite were the same as for TIROS VII operations.

Only the TIROS CDA ground stations had full capability for programming the satellite. The three primary CDA stations were used for commanding or programming picture-taking sequences, for receiving and processing sun-angle and telemetry data, and for receiving and processing the TV pictures transmitted by the satellite. The three CDA stations were located at Wallops Island, Virginia; San Nicolas Island, California; and Fairbanks, Alaska. The back-up CDA station, located at the Astro-Electronics Division of RCA, had the same capabilities as the primary CDA stations. This station was used, as necessary, during the operational period of TIROS VIII to perform engineering evaluations and checks of satellite operation. In addition, the back-up station assumed CDA responsibility during periods when the Wallops Island CDA station was inoperable.

The stations of the NASA Minitrack Network tracked the satellite to obtain attitude indicator and ephemeris data for use by the NASA TIROS Technical Control Center (TTCC) in formulating command programming data for the CDA stations and satellite position data for the APT and CDA stations.

The areas of the earth to be photographed by the satellite were determined by the U.S. Weather Bureau and specified by request to NASA. These requests were examined at the TIROS Technical Control Center of NASA's Goddard Space Flight Center (GSFC), and became the basis for the operating command programs prepared for the CDA stations. Detailed program instructions were teletyped from TTCC to the cognizant CDA station, where they were used in entering command programs in the stations's instrumentation control equipment. The program instructions specified, (in terms of command equipment programs) the areas to be photographed, the camera subsystem or subsystems to be used, the order in which the camera subsystems were to be used, and the number of "set pulses" to be sent to program the satellite's clocks so that remote picture-taking would begin at the desired place in the orbit.

When the satellite came within communication range of the CDA station, the preset program was transmitted to the satellite. During the satellite ground station contact period, telemetry and picture data was received by the ground stations and command programs were transmitted to the satellite. Depending on the predicted duration of the contact and on the desired satellite operations, direct picture operation of one or both camera subsystems could be commanded during a contact.

V. TV PICTURE SUBSYSTEMS

A. FUNCTION

1. Camera Subsystem No. 1

Camera subsystem No. 1 was a standard TIROS television camera subsystem comprising a 1/2-inch, 500-line vidicon TV camera; a camera electronics package containing deflection circuits, power supplies, and video circuits; a magnetic tape recorder containing a coaxial-reel video tape transport, erase, record, and playback tape heads, signal circuits, a drive mechanism and drive motor, and motor control circuits; and a 235-Mc FM video transmitter. The TV camera was equipped with an Elgeet-Navitar wide-angle lens providing a 104-degree (diagonal) field of view. At the mean orbit altitude of 450 statute miles, the camera viewed an earth area of approximately 500,000 square miles.

Camera subsystem No. 1 was capable of independent picture taking in either of two operating modes and of picture transmission in one of the picture taking modes as well as in the tape recorder playback mode. The direct mode of operation of camera subsystem No. 1 was used when pictures were to be taken while the satellite was within communications range of a CDA ground station. In this mode, the satellite responded to a real-time command from the ground station by transmitting pictures to the station as they were being generated by the camera. This mode required no video storage; however, the video electronics circuits of the tape recorder were used in the direct mode to impress the video signal as frequency modulation on an 85-kc subcarrier which, in turn, was frequency modulated on the 235-Mc transmitter carrier.

The remote operating mode was used when pictures were to be taken while the satellite was at a position in orbit remote from any of the three ground stations. This mode was programmed by a CDA station when it transmitted a remote command message to the satellite containing a delay period that could range from 2 seconds up to 5 hours in 2-second increments (an orbit period was 99.35 minutes). This delay-period command was stored in the satellite and counted out by a satellite clock (physically located in the instrumentation control subsystem). At the end of the delay period, picture taking was automatically initiated and a sequence of 32 pictures was taken. Picture video, modulated on the 85-kc subcarrier, was recorded on one track of the video tape recorder. The tape recorder operated only during the individual picture readouts, remaining inactive in the intervals between pictures.

When the satellite next passed within communications range of a CDA station, the playback mode of operation was commanded by the station and the satellite responded by playing back and transmitting the stored picture data. At the ground station the picture data was received, demodulated, recorded on video tape, and presented as a kinescope display for photographic recording on a 35-mm film strip.

Each TV transmission of direct or remote pictures from camera subsystem No. 1 was accompanied by sun-angle data that originated in two or three of nine sun sensors that were equally spaced about the periphery of the satellite. A separate 10-kc subcarrier, modulated on the 235-Mc TV carrier, conveyed the sun-angle information. As the satellite rotated and each sensor, in turn, scanned the sun, each sensor produced a pulse have one of three characteristic widths. The pulse widths were assigned to the sensors in a manner such that any combination of two consecutive pulses was unique, permitting the orientation of the TV camera with respect to the sun to be derived. As the pulses were being produced by the sensors, they were converted to 10-kc bursts of the same durations as the original pulses by circuits in the satellite's tape recorder electronics. In the direct mode of picture taking, these 10-kc bursts were combined with the video subcarrier before it was fed to the TV transmitter. During remote picture taking, the 10-kc bursts were recorded on a separate channel of the tape recorder. When the tape recording was played back for transmission of recorded data to a ground station, the 10-kc bursts were reconstituted (to ensure a sun-pulse subcarrier frequency of exactly 10 kc) and then combined with the video subcarrier. The combined video subcarrier and sun-angle signal were applied to the TV transmitter. This data, in addition to satellite attitude data, was used to determine the orientation of each picture frame. The sun-angle pulses also provided a convenient means for determining satellite spin rate.

Camera subsystem No. 1 TV transmissions from the satellite were received at one of the three CDA ground stations and fed to two receivers connected for polarization-diversity reception. Bandpass filters were used to separate the video subcarrier from the sun-angle subcarrier. The video subcarrier was demodulated and the resultant signal was applied to video electronics circuits for display on a kinescope and to a magnetic tape recorder for storage. A time-reference signal derived from the video signal was applied to an index computer which generated a picture frame number, in binary form, for display on a panel adjacent to the kinescope screen. The index computer also used signals generated internally in the ground equipment to provide index data for identifying the satellite, the camera subsystem that produced the picture, the orbit number, and the real time in GMT at which the picture was received by the ground station, all of which were also displayed on the kinescope panel.

The sun-angle data, after being separated from the video signal, was fed to a sun-angle computer. This computer provided data for display by a number-lamp

presentation on the kinescope panel. The kinescope screen and panel, including the index and sun-angle data, was photographed by an automatically operated, 35-mm camera whose shutter was synchronized with the TV signal.

2. Camera Subsystem No. 2

Camera subsystem No. 2, the APT camera subsystem, consisted of a high-persistency, 800-line, slow-scan vidicon camera; a camera electronics module containing deflection circuits, power supplies, and video circuits; an FM transmitter; camera and transmitter control circuits; and a special telemetry conditioner for adapting telemetry voltage levels in the APT subsystem to the standard TIROS telemetry commutator. The APT camera was provided with a Kinoptic Tegea wide-angle lens having a 104-degree field of view (diagonal), a focal length of 5.7 mm and a lens speed of f/1.8. At the mean satellite altitude (450 statute miles), an APT picture encompassed an area approximately 850 miles on a side (assuming zero camera nadir angle) and provided a ground resolution of 1.2 miles per TV line.

Camera subsystem No. 2 was capable of independent picture taking in a direct or a remote mode, although the remote mode differed from that of camera subsystem No. 1 in that the picture data was not recorded. In both modes, the pictures were transmitted in real time to any APT station within range of the satellite's APT transmitter during the 200-second readout scan of the vidicon. In the direct mode, picture taking was commanded directly by a CDA station. In the remote mode, a CDA station transmitted an APT remote program to the satellite. The remote program contained a picture-delay message which was stored in the satellite and counted out by a clock circuit in a manner similar to that of camera subsystem No. 1. When the delay period was completed, picture-taking was initiated automatically and eight cycles of picture taking followed. The first cycle was used for warming up the camera circuits and was not used to obtain useful picture data; the useful picture count of the sequence was therefore seven pictures.

The APT camera employed a special high persistency one-inch vidicon with an 800-line scan pattern. This vidicon permitted a very slow (200-second) readout of the exposed image to obtain a high resolution TV picture with a relatively narrow video bandwidth. The narrow video bandwidth, in turn, made it possible to receive the APT pictures using relatively simple local APT station equipment.

The APT pictures were spaced at intervals of approximately 215 seconds. The actual interval between pictures was determined by the occurrence of a sun pulse generated by one of the satellite's nine sun-sensors. Each picture cycle was initiated by the occurrence of the first pulse from this sensor occurring after a fixed delay from the end of the preceding picture. The fixed angular

relationship between the position of the sensor and the position of the camera on the satellite's baseplate, in addition to the satellite's spin rate, was sufficient information to determine the time delay between the sun pulse and camera shutter operation, from which the orientation of the camera with respect to the sun line at the time of picture taking was determined. From the positions of the satellite and the sun with respect to the receiving station at the time of picture taking, the geographic directions in the picture were determined.

The APT picture-taking cycle lasted for 208 seconds from the time it was initiated by the sun pulse. The cycle consisted of an 8-second prepare-expose-develop (PED) period, in which the vidicon was conditioned to take the picture and the shutter was operated, and a 200-second readout period, in which the exposed image on the vidicon photoconductor was scanned to generate the television signal. The fixed preparation period preceding shutter operation was taken into account in the determination of picture orientation. This period was measured during calibration of the satellite (5.475 seconds for TIROS VIII) so that the method of picture orientation described above could be used.

The signal from the APT transmitter was received at a CDA or APT ground station by a circularly polarized helix antenna, and was fed to an FM receiver. The antenna tracked the satellite in transit using tracking data supplied to each APT and CDA station by TTCC. The receiver output was processed by facsimile recording equipment to produce real-time cloud-cover pictures of the locale of the particular ground station.

At the beginning of the 208-second picture cycle, a "start" tone was transmitted from the satellite to the ground for 3 seconds, automatically switching the ground station facsimile equipment from the standby mode to the operating mode. During the next 5 seconds, phasing pulses were transmitted to the ground station to synchronize the facsimile equipment with the satellite's vidicon scanning beam. The 200-second image printout which followed was reproduced line-by-line on the facsimile equipment as the photoconductor was scanned in the vidicon.

B. PERFORMANCE EVALUATION

1. General

The TIROS VIII satellite produced picture data, both for meterological use and for experimental study, that was highly satisfactory in quantity and useability, and which was available over an exceptionally long total operating period in orbit. Camera subsystem No. 1, the standard TIROS camera subsystem, produced over 97,000 pictures during the first 24 months of operation in orbit, over 92 percent of which were characterized by good quality and useability. Camera subsystem No. 2, the APT camera subsystem, which was experimental on TIROS VIII,

produced over 4,000 pictures in the five-month period of use and provided highly useful information concerning the use of the subsystem in a world network and its development for later satellites of both the spin-stabilized and non-spinning (earth-oriented) types. Problem areas encountered in this experimental application of the APT camera subsystem were studied and advances were made toward the technical improvement of the subsystem for future meteorological satellite applications.

2. Camera Subsystem No. 1

a. General

Camera subsystem No. 1 returned 97,156 pictures in the 24-month period covered by this report, of which 89,963 (92.6 percent) were useful for meteorological analyses. From these pictures, 2,825 nephanalyses were prepared and 799 weather bulletins were released to various weather bureaus and to units of United States military organizations located around the world. At the conclusion of the evaluation period covered by this report, camera subsystem No. 1 was still functioning and returning pictures of usable quality. The generally high quality of the pictures received throughout the period from camera subsystem No. 1 is evident in the pictures presented in Section III of this report.

b. TV Camera and Camera Electronics

An analysis was made of pictures taken by camera subsystem No. 1 beginning on orbit 30 and extending through orbit 11,014. In the case of remote sequences, the first and last frames and a frame near the middle of the sequence were examined. The results of this analysis are listed in Table V-1, given as percentage deviations from the specified nominal values for the TIROS television pictures.

In the pictures examined, the measurements were within specified limits on all orbits with the exception of the horizontal centering error. The vertical centering error, the horizontal and vertical size errors, and the aspect ratio errors were all within specified limits for every orbit examined. The maximum vertical centering error was 2.3 percent (compared with the 2.5 percent limit); the maximum horizontal size error was 2.6 percent (compared with the 5 percent limit); the maximum vertical size error was 4.6 percent (the limit value is 5 percent); and the maximum aspect ratio error was 5 percent (no limit is specified).

TABLE V-1. PICTURE MEASUREMENTS, CAMERA SUBSYSTEM NO. 1

Orbit No.	Frame No.	Picture Mode	Centering Deviation (%)		Size Deviation (%)		Aspect Ratio Deviation (%)
			Horiz.	Vert.	Horiz.	Vert.	
30	1	Tape	-1.5	1.5	-0.2	-0.7	1.0
30	16	Tape	-1.5	1.5	0.5	0	0
30	32	Tape	-1.5	2.3	0.5	0	-1.0
31	6	Tape	-2.3	2.3	0.8	-0.4	0
31	16	Tape	-1.5	2.3	0.8	-0.4	0
31	32	Tape	-2.3	2.3	0	-1.1	0
230	2	Tape	-1.4	2.2	-	-0.4	-
230	16	Tape	-1.4	1.4	1.0	0	0
230	29	Tape	-2.1	1.8	1.0	-0.5	0
344	16	Tape	-1.4	1.5	1.0	-1.0	0
344	28	Tape	-0.7	2.2	1.0	-0.4	1.0
434	7	Tape	-0.35	1.5	1.6	0.0	0
434	16	Tape	-1.0	1.1	-0.1	-1.0	0
434	32	Tape	-0.3	1.1	0.9	-1.0	-1.0
587	12	Tape	-0.4	0.7	0.5	-1.5	-2.0
718	1	Direct	-1.1	0.7	2.0	3.4	1.0
718	5	Direct	0	0.7	1.5	2.6	0
718	4	Tape	0.4	0	1.0	1.1	1.0
718	14	Tape	0.8	0.4	1.5	-0.2	0
845	6	Tape	0	-0.4	1.9	-0.2	-2.0
945	1	Direct	-2.6	2.2	1.6	4.0	1.0
945	16	Direct	-2.6	2.2	2.4	4.6	1.0
945	24	Direct	-1.8	2.2	2.4	4.0	0
945	1	Tape	1.1	0	2.4	1.9	0
945	16	Tape	1.1	0.7	1.6	1.9	1.0
945	31	Tape	0.7	0.7	1.1	1.1	0

TABLE V-1. PICTURE MEASUREMENTS, CAMERA SUBSYSTEM NO. 1
(Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviation (%)		Size Deviation (%)		Aspect Ratio Deviation (%)
			Horiz.	Vert.	Horiz.	Vert.	
1046	6	Tape	1.5	0.4	0.9	1.4	0
1046	15	Tape	1.5	0.4	2.6	2.0	0
1046	31	Tape	1.8	0.7	2.4	1.9	0
1149	13	Tape	2.3	-0.7	0.8	-0.4	0
1149	31	Tape	2.3	-0.4	0.8	-0.5	-1.0
1252	17	Tape	1.1	--	2.4	--	--
1252	31	Tape	1.1	--	2.4	--	--
1302	16	Tape	1.23	-0.98	0.0	0.75	2.19
2008	19	Tape	2.85	0.58	0.65	1.20	2.53
2610	13	Tape	2.17	0.58	0.65	1.09	2.80
3020	15	Tape	-1.73	0.98	-0.66	-2.40	0.0
3426	1	Direct	-3.67	1.07	-1.32	1.23	1.86
4037	3	Tape	2.72	1.08	-1.97	0.75	1.27
4496	17	Tape	-4.21	-1.40	1.66	1.27	4.68
5053	8	Tape	4.20	0.4	0.730	0.691	7
5053	9	Tape	3.87	1.3	0.730	0.710	0
5053	10	Tape	3.83	0.5	0.743	0.734	35
5053	11	Tape	4.25	0.25	0.741	0.750	0
5512	12	Tape	4.44	0.97	0.737	0.726	38
5512	13	Tape	3.77	0.37	0.740	0.739	0
5512	14	Tape	4.51	0.46	0.728	0.722	0
6014	14	Tape	3.51	0.26	0.744	0.748	0
6014	15	Tape	3.39	0.15	0.758	0.743	33
6014	16	Tape	3.39	0.26	0.744	0.749	0

TABLE V-1. PICTURE MEASUREMENTS, CAMERA SUBSYSTEM NO. 1
(Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviation (%)		Size Deviation (%)		Aspect Ratio Deviation (%)
			Horiz.	Vert.	Horiz.	Vert.	
6572	15	Tape	3.45	1.7	0.740	0.770	5
6572	16	Tape	3.13	1.67	0.746	0.727	0
6572	17	Tape	3.81	0.71	0.747	0.756	0
7065	1	Tape	3.83	0.86	0.741	0.745	0
7065	2	Tape	4.29	0.32	0.742	0.744	0
7065	3	Tape	4.39	0.26	0.739	0.748	0
7549	18	Tape	4.27	0.25	0.755	0.757	0
7549	19	Tape	4.81	0.34	0.754	0.760	0
7549	20	Tape	4.85	1.18	0.753	0.763	2
8036	14	Tape	3.40	0.41	0.739	0.750	0
8036	15	Tape	3.07	0.62	0.739	0.751	1
8036	16	Tape	3.32	0.62	0.741	0.753	1
8762	13	Tape	3.47	0.51	0.766	0.760	0
8762	14	Tape	3.70	0.26	0.739	0.767	3
8762	15	Tape	4.19	0.25	0.752	0.761	0
8952	3	Tape	4.20	0.11	0.735	0.743	1
8952	4	Tape	3.89	0.23	0.742	0.760	0
8952	5	Tape	4.83	0.12	0.735	0.744	0
9567	26	Tape	5.23	0.61	0.757	0.747	0
9567	27	Tape	4.60	1.22	0.754	0.760	1
9567	28	Tape	4.45	0.29	0.766	0.755	0

TABLE V-1. PICTURE MEASUREMENTS, CAMERA SUBSYSTEM NO. 1
(Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviation (%)		Size Deviation (%)		Aspect Ratio Deviation (%)
			Horiz.	Vert.	Horiz.	Vert.	
10,055	2	Tape	3.76	0.24	0.730	0.738	2
10,055	3	Tape	3.96	0.48	0.729	0.741	3
10,055	4	Tape	3.52	0.47	0.740	0.741	4
10,499	8	Tape	3.52	0.36	0.744	0.744	2
10,499	9	Tape	4.03	0.29	0.740	0.740	4
10,499	10	Tape	3.18	0.27	0.739	0.746	4
11,014	3	Tape	3.14	0.15	0.729	0.745	2
11,014	4	Tape	4.54	0.15	0.740	0.738	5
11,014	5	Tape	4.34	0.69	0.737	0.744	4

In the pictures examined, picture resolution and contrast were, in general good up until October 1965, when a decline in picture contrast began to be evident.

c. Tape Recorder

(1) General

Tape recorder performance was generally satisfactory, as inspection of the playback frames reproduced in Section III of this report shows. However, two problem areas were encountered which required investigation and these are reported in detail in the following paragraphs. One of these problems, involving the loss of some frames or parts of frames from remote sequences, was largely eliminated when its temperature dependency was discovered and satellite attitude programming was altered to provide a more favorable baseplate temperature range. The other problem, though less severe, was progressive and irreversable and continued throughout the evaluation period. This problem was one of dropouts in the tape-recorded video signal in some of the frames of remote sequences.

(2) Incomplete and Missing Playback Frames

The problem of incomplete and missing playback frames was apparent early in the operational life of TIROS VIII and an investigation of the problem was begun in January 1964. Data was accumulated from orbits 530 through 920 showing that the number of missing frames ranged from 0 to 29 in the 32-frame sequence. This data is presented in Figure V-1. Examination of the 35-mm film strips for these sequences showed that the effect was most severe at the beginning of a recorded sequence. (Frame 32 of the playback sequence is frame 1 in the order of recording.) Furthermore, when partial frames occurred, the part of the frame that was missing was the first part in the order of recording and the missing portion was largest on the earliest recorded frames and grew progressively smaller in each successive frame as the recording sequence proceeded.

Two other early observations were (1) a definite correlation existed between satellite temperature and the frequency and severity of the problem, and (2) a definite correlation existed between the severity and frequency of the problem and the time lapse between the end of a tape recorder playback and the beginning of the recording sequence. In the first instance, as satellite baseplate temperature increased, the problem decreased. In periods of 100 percent sun time, the problem disappeared. In the second instance, the problem became less severe as the time lapse between a playback and a recording sequence decreased.

The first test in this investigation was an operational test for trouble isolation of the problem. This test involved the transmission of special "direct-remote" programs to the satellite (these are used only in engineering investigative programming) in which the camera subsystem is programmed for a remote sequence with a minimum delay time and is kept in a playback mode until the camera clock alarms for the start of the remote sequence. In this mode, the timing and control signals in the camera subsystem are the same as in a remote recording mode except that the pictures taken by the camera are transmitted directly to the ground without being recorded. Sequences received in this mode of operation during the test were complete (32 frames) and all frames were of normal length. This test demonstrated that camera subsystem timing in the remote mode was normal. The operation of the transmitter and camera was not in question since both performed normally in the direct mode of operation. Therefore, the problem was known to be in the tape recorder.

The nature of the problem suggested three possible causes within the tape recorder, as follows:

(1) Tape acceleration was not rapid enough for the tape to reach recording speed before the start of camera readout.

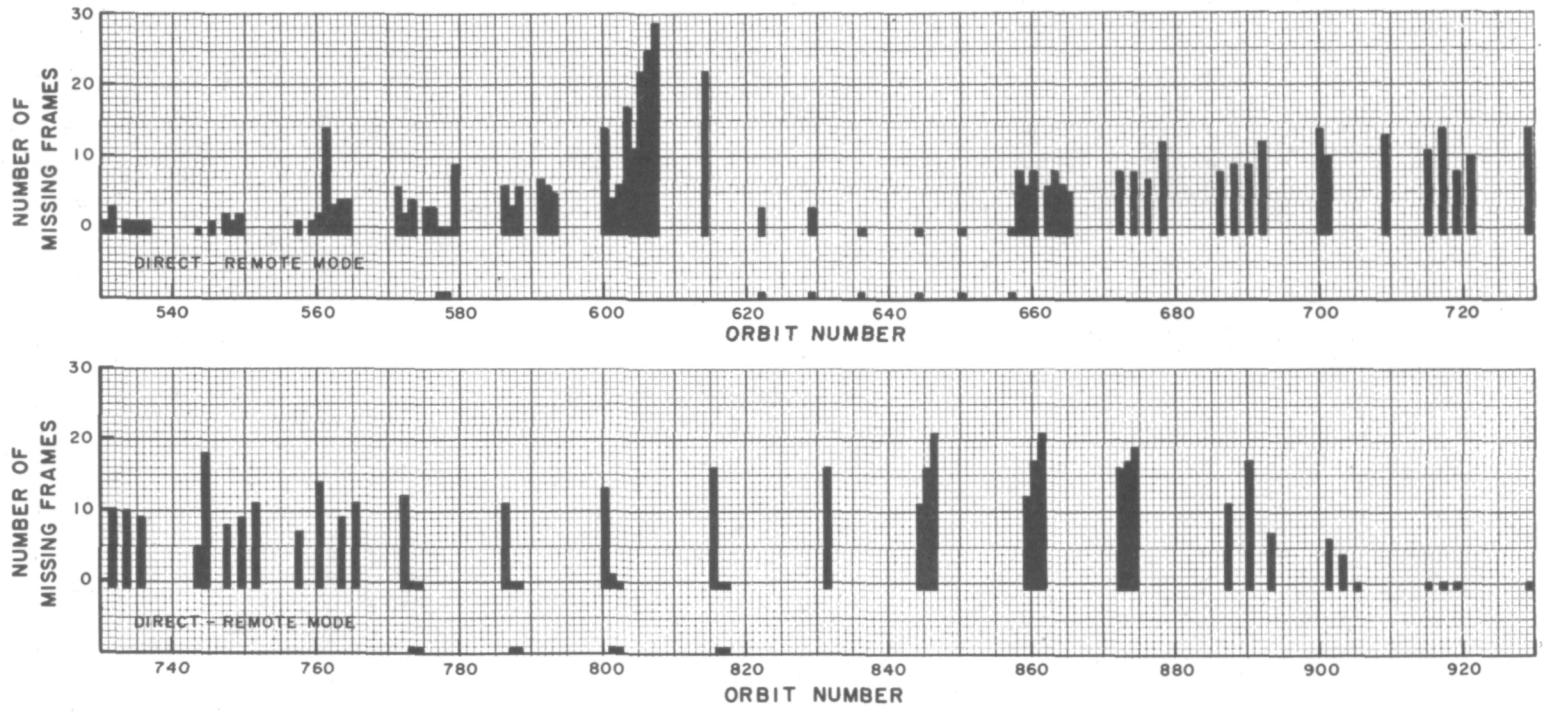


Figure V-1. Missing Playback Frames, Orbits 530 through 920

(2) Start of tape acceleration was too late to allow the tape to reach recording speed before the start of camera readout.

(3) Subcarrier modulator electronics turned on after the start of camera readout.

In order to determine which of the above was responsible for the problem, the ground station magnetic tape recording of a typical remote sequence (orbit 572) in which the problem was present was played back and the subcarrier timing was analyzed. The normal video subcarrier has a peak-to-peak signal voltage of 1.0 volt and its duration is two seconds per frame. The individual frame envelopes are normally separated by an interval of one second, during which the signal level is zero volts. Each interval includes the time required for the tape transport to coast to a stop after completion of a frame and the time required for acceleration to recording speed at the start of the next frame. On orbit 572, the first six frames were entirely missing and the first frame received was playback frame 26, 70 percent of which was missing. The missing portion decreased gradually on succeeding frames and had decreased to 10 percent by frame 14.

Two time measurements were made. One was the interval between frames, which would certainly reveal any variations in acceleration time. (The deceleration or coast period was assumed to be constant and was irrelevant since it could only act to decrease the acceleration time below normal.) The measured durations of all of the interframe intervals were 1.0 ± 0.1 second, indicating that the acceleration time was not varying.

The second measurement made was the elapsed time from the end of the subcarrier envelope for one frame to the end of the subcarrier envelope for the succeeding frame. If the subcarrier modulator electronics were turning on late, this time period would be constant. Measurement showed that this time period varied. Therefore, the cause of the problem was known to be the late start of the tape transport in the period preceding the frame. The start time was earlier on each successive frame until, in most cases, it became normal at some point in the sequence.

Next, the time delay circuit which controls the start of operation of the tape transport was analyzed theoretically to determine which components could be responsible for late starting. A schematic diagram of this circuit is shown in Figure V-2. The supply voltage (RUN TAPE power) is applied to the circuit two seconds in advance of a camera readout. Capacitor C1 begins charging toward the zener-controlled voltage V_{Z1} at an exponential rate with a time constant of R1C1. When the voltage across C1 exceeds V_{Z2} by a few tenths of a volt, Q1 begins to conduct. Q2 and Q3, in turn, also begin to conduct. When Q3 conducts, the feedback circuit to the base of Q1 causes Q1 to conduct harder

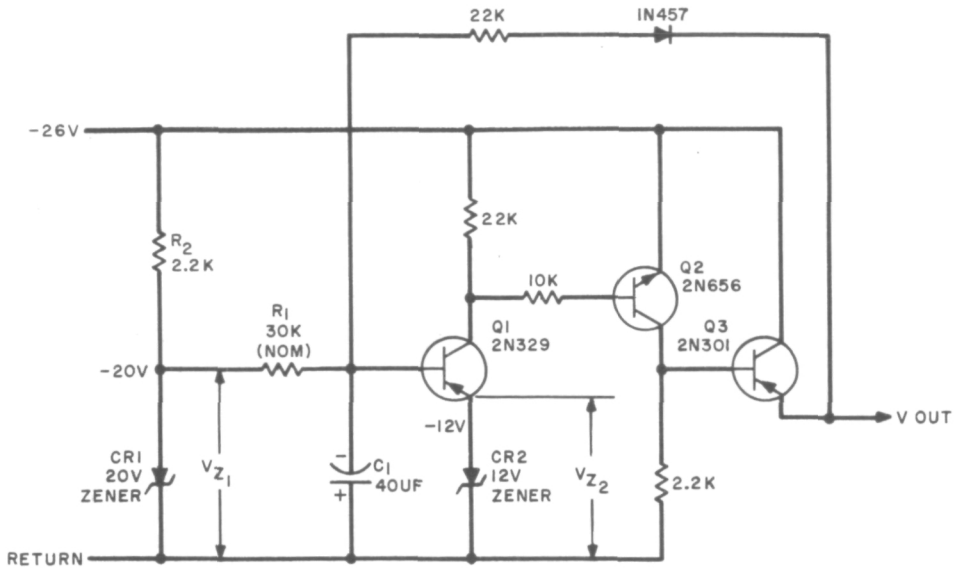


Figure V-2. Schematic Diagram of Tape Recorder Start Circuit

which has a rapidly regenerative effect through Q2 and Q3, driving all three transistors into heavy conduction and providing the output current from Q3 to drive the tape transport inverter. The nominal delay provided by this circuit is 1.2 seconds, allowing 0.8 second for recorder acceleration time before picture readout begins. (The maximum acceleration time under normal conditions is 0.5 second.) The purpose of the delay is to conserve tape recording capacity by allowing no more time for tape acceleration than necessary.

Three possible conditions could bring about the increase in delay. They are:

(1) Temperature variations,

(2) Voltage variations, and

(3) Aging of components.

The effects of voltage and temperature variations were investigated experimentally in laboratory testing. Using a motor drive unit and tape transport manufactured for TIROS Series I spacecraft, the time delay and the recorder acceleration were measured as functions of temperature and supply voltage.

Over a voltage range of 20 to 28 volts, and a temperature range of -30°C to +25°C, the time delay remained within specified limits. Moreover, after two years of shelf storage, the time delay was the proper value, 1.2 seconds, during the first operation.

For the acceleration tests, the motor drive unit was driven by a 4-second pulse occurring at 500 pps. The total number of frames that could be recorded on the tape was counted over a voltage range of -22 to -28 volts and a temperature range of -20 to +25°C. The variation was from 30 to 32 frames. The actual acceleration time was measured at room temperature over a voltage range from -20 to -28 volts. The acceleration time varied between 0.35 and 0.6 second over this voltage range. The maximum available acceleration time under normal conditions, 0.8 second, could not be exceeded except by using a transport with very stiff bearings at a supply voltage of -20 volts.

These tests showed that the problem was not related to voltage variation since only extremes of voltage variation could cause changes of the magnitude consistent with TIROS VIII operation and extremes such as those applied in the tests were not experienced by the TIROS VIII satellite. Even these extremes could not cause the amount of change observed on TIROS VIII unless the tape transport bearings were abnormally stiff, a condition for which there is no evidence on TIROS VIII. Further evidence confirming that voltage change was not responsible for the problem was the fact that the problem was absent when a remote sequence followed promptly after playback, a time when the satellite had just experienced heavy loads and when power supply voltage might be expected to be low. These arguments would not apply, of course, if battery voltage were abnormally low because of inordinately heavy programming loads coupled with periods of low solar energy input, a condition which is normally avoided by observing routine precautions in programming so as not to expend more than the predicted energy input during an orbit.

The tests of tape transport operation also indicated no temperature dependency of the problem. However, this was contradictory to evidence of temperature dependency of the problem on TIROS VIII. At approximately orbit 4000, the attitude of TIROS VIII was changed to obtain a higher baseplate temperature. This attitude change virtually eliminated the problem and confirmed beyond any doubt that the problem was dependent on temperature.

The final conclusion as to the specific cause of this problem must necessarily be theoretical. Referring to the delay circuit once again, transistors Q2 and Q3 can be eliminated from suspicion, since any adverse change in their performance would be evidenced by an increase in acceleration time, and this has not been observed. Correspondingly, Q1, which supplies the current drive to Q2 can also be eliminated, since any decrease in the Beta of Q1 due to aging or temperature changes would also result in an increase in acceleration time.

This leaves only the zener diodes, resistors and the capacitor to be considered. The time delay is a function of zener voltage. As the 8-volt difference between V_{Z1} and V_{Z2} decreases, the time delay increases. However, this difference would have to decrease to 0.5 volt, or less, to cause 70 to 100 percent of the frames to be short. Zener diodes are normally stable over large temperature ranges and these particular diodes are rated for operation over a temperature range from -65°C to +150°C. The operating range of the TIROS VIII baseplate was from -8° to +10°C. It is difficult to imagine any change over this range which could produce the time delay differences observed and which would, furthermore, be reversible.

Changes in resistance of R1 and R2 (particularly R1) could affect the time delay. Again as in the case of the diodes, it is difficult to conceive that a change in resistance, on the order of magnitude of the change required to produce the problem, could occur over such a small temperature range, except as the result of a catastrophic failure, which of course would not be reversible.

The only component remaining to be considered is the capacitor C1. The capacitor is a 40 mf 30 VDC, Commercial Fansteel style PP, wet-slug tantalum type. The leakage current for the tantalum capacitor is 0.02 microampere per microfarad per volt. The leakage resistance for this 40 mfd capacitor is thus 1.2 megohms. Data sheets on this type of capacitor state that such low leakage values are only to be obtained after voltage has been applied for 5 minutes. Manufacturers do not state what the leakage may be immediately after voltage application.

Variations in leakage resistance will obviously affect the time delay. This has been demonstrated by paralleling the capacitor with a variable resistor to simulate the leakage resistance, then measuring the time delay as the leakage resistance is varied. The results are shown in Figure V-3. The leakage resistance increases with time after the voltage application. This is consistent with the observed problem pattern, i.e., picture length increased (delay decreased) as the recording sequence progressed.

Capacitors containing a wet electrolyte undergo a forming process each time voltage is applied. When the voltage is applied, a dielectric film is deposited on the anode out of the electrolytic solution. The amount and nature of the dielectric film determine the value of the capacitance formed. Wet tantalum electrolytics have a storage life of from two to five years. However, while the capacitor is idle, the tantalum oxide film is attacked by the active electrolytic bath and will exhibit varying rates of d-c leakage current decay upon initial application of voltage. The rate of decay depends on the storage interval, storage temperatures, applied voltage, temperature during use, and film quality. It is for this reason that d-c leakage is only specified for five minutes after voltage application. Most wet electrolytics form very quickly and exhibit very high

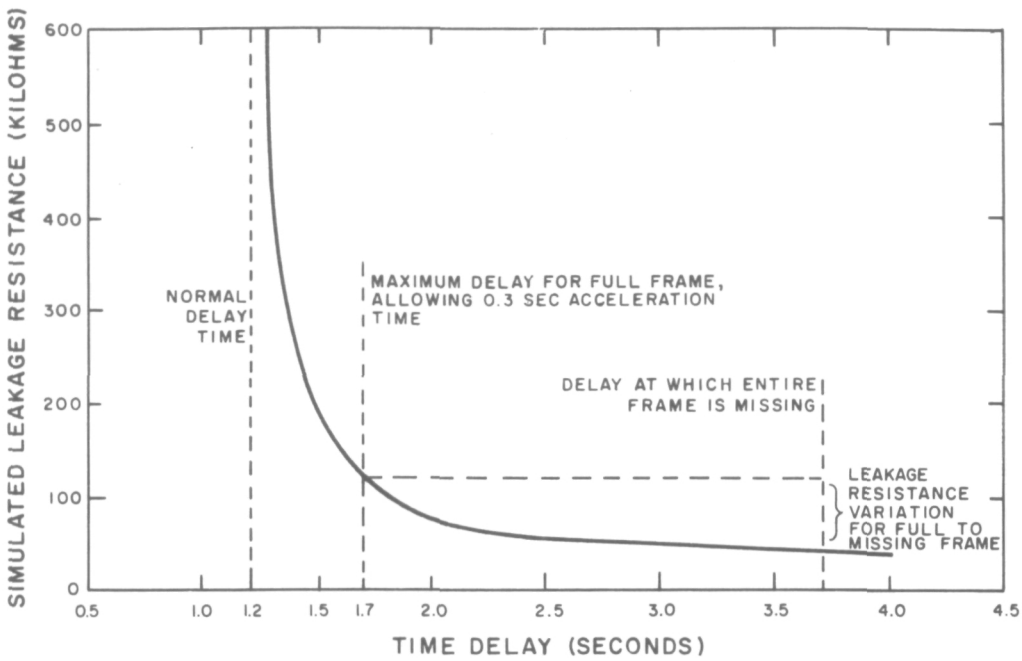


Figure V-3. Variation in Time Delay vs Simulated Leakage Resistance for Tape Recorder Start Circuit

leakage current decay rates; however, it must be expected that occasionally one will exhibit the slow characteristics allowed for by the manufacturer's five-minute timing period, particularly as component life increases.

The effect of temperature on the forming of a wet capacitor (leakage current decay) is shown in Figure V-4. The curves indicate qualitatively the change in leakage current decay with temperature variation. Quantitative values cannot be assigned to these general characteristics because of the many parameters and tolerances involved. The values do indicate, however, that a favorable leakage current decay rate increase can be expected with an increase in temperature. This fact also agrees with the problem pattern in which the pictures increased to normal size (delay decreased to a normal value) as satellite temperature increased.

In summary, capacitor C1 could produce the problem of short pictures, could follow the problem pattern of the pictures increasing to normal duration as the recording sequence progressed, and could return to normal operation at higher temperatures. In particular it is significant that the sequence timing and temperature reversibility patterns are consistent with the problem. No other circuit component exhibits the characteristics necessary to produce these patterns.

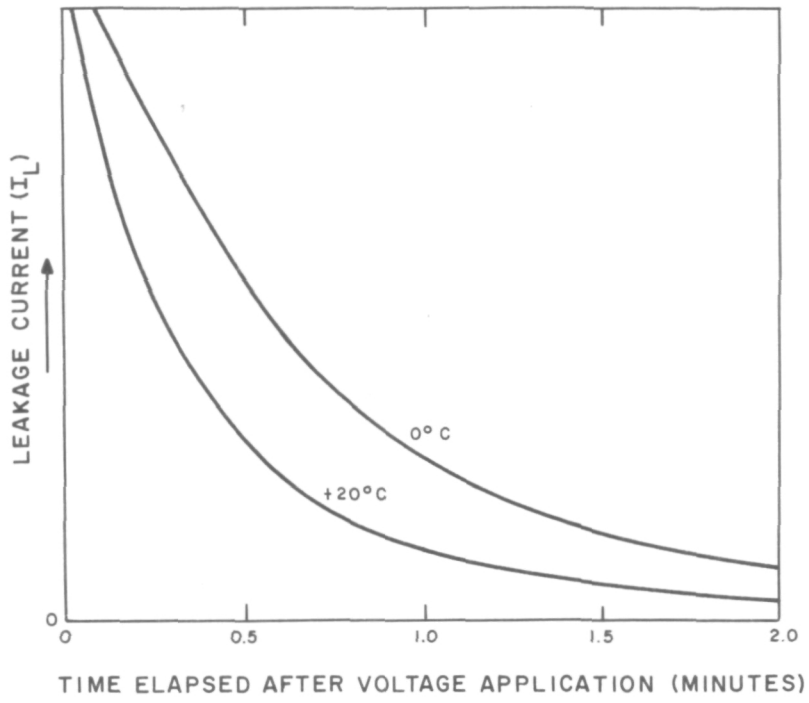


Figure V-4. Wet Capacitor (C1) Forming Time at 0°C and at +20°C

It is therefore postulated that the capacitor underwent an aging change, after which temperature changes from +5 °C to -8 °C caused the time delays observed during the problem period. During the recording cycle, as the voltage was applied in 4-second steps, at 30-second intervals, the forming process of the capacitor was cumulative; there was negligible reversal of the forming process in the 30-second interval between pictures. As the forming increased, the delay approached normal. Thus, remote sequences programmed to start immediately after a 100-second playback period did not exhibit this problem.

A solid (dry) tantalum capacitor is recommended for future use in this application. Solid tantalum capacitors, when compared with wet types, have a more stable d-c leakage characteristic and exhibit a more rapid d-c leakage current decay after extended storage intervals. Since there is no liquid present in these capacitors, they will withstand longer storage periods with no degradation of the dielectric film or d-c leakage. In addition, solid tantalum capacitors have a longer life in vacuum and are more stable over varying temperatures and in radiation environments.

As a result of this investigation, a sleeved, high reliability, preconditioned dry tantalum capacitor, rated at 39 mfd, 35 VDC was recommended for this application. The overall physical dimensions of the recommended capacitor are slightly smaller than those of the wet tantalum capacitor used on TIROS VIII.

(3) Tape Dropouts

The dropout of the recorded video signal on individual TV lines, and portions of TV lines, affected from one to six frames of many of the remote picture sequences. On earlier orbits, only one line of frame 32 was affected. After a year of operation in orbit, frames 3, 22, 24, 26, 27, and 32 were consistently affected. The dropouts were similar in appearance to noise streaks. Occasionally, they would cause loss of sync and result in picture tear. The constancy of these patterns, always occurring at the same positions on the same frames, left little doubt that their origin was tape dropout. Other possible causes of noise streaks would result in a more random appearance on individual lines and would be more consistent in appearing on all frames of a sequence. Figure V-5 shows an example of this condition in its severest form.

This problem was identical in its effect on the pictures to the tape dropout problem encountered on the TIROS VII satellite and reference is made here to the account of that problem presented in the TIROS VII Post-Launch Evaluation Report.

In brief, it is believed that shavings of the mylar backing of the magnetic tape were scraped from the tape by the end-of-tape sensing bars. These minute mylar particles collected on the sensing bars. They occasionally worked loose and were transported on the back (non-recording side) of the tape into the take-up reel. In the reel the back of the tape in one winding contacted the front

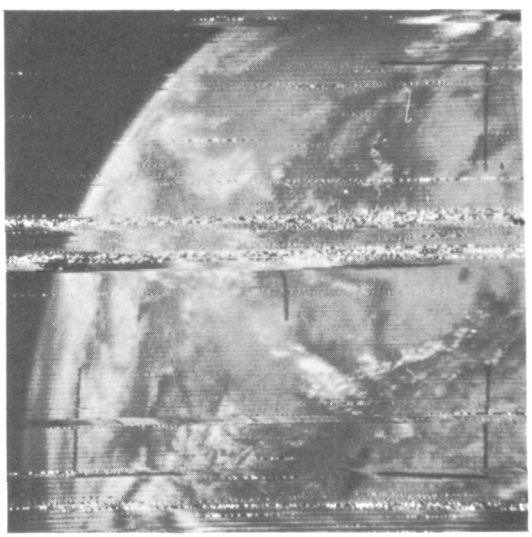


Figure V-5. Orbit 8067, Camera 1, Remote, Frame 32, Showing Tape Dropout in its Severest Form

(recording side) of the tape in the next winding. It is hypothesized that, as a result of this contact, the shavings become imbedded in the recording surface of the tape, forming small areas on the tape that would no longer respond to the recording flux. The mechanism by which this problem is believed to have occurred is illustrated in Figure V-6.

d. TV Transmitter

The camera subsystem No. 1 TV transmitter performed normally throughout the period of evaluation. Signal strengths reported by the CDA ground stations indicated that power output of the transmitter was greater than the specified minimum of two watts. The consistently good quality of the TV pictures received from this system indicated proper modulator performance.

3. Camera Subsystem No. 2

a. General

Camera subsystem No. 2, the government-furnished APT camera subsystem, produced a total of 4,044 pictures in the five-month period from

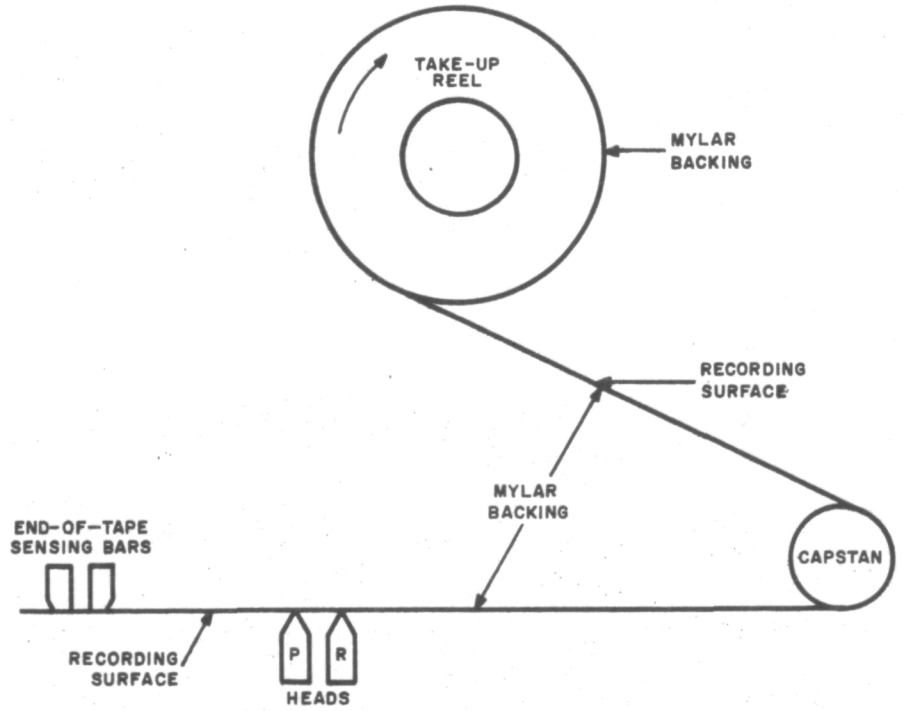


Figure V-6. Diagram of Tape Transport Showing Relationship between Recording Surface and Mylar Backing during Remote Picture Taking

December 21, 1963 to May 22, 1964 in which it was programmed for operation. These pictures were not evaluated for meteorological usefulness because of the experimental nature of the subsystem in its use on the TIROS VIII satellite. However, APT pictures and subsystem performance were evaluated and analyzed by RCA engineering personnel using government-furnished APT ground station equipment installed for that purpose at the AED facility. A summary of APT performance as observed at the AED ground station is given in the following paragraphs.

b. APT Camera and Camera Electronics

TV picture facsimiles produced by the APT camera are reproduced in Section III of this report. These pictures may be of special interest because they are among the first pictures to be returned from space and recorded by the unique equipment and techniques of the APT subsystem. The capability of the subsystem for producing high picture quality and good definition in clouds and land objects is immediately recognizable, in spite of several distorting modulation patterns that are consistently present in the pictures. These patterns include a uniformly recurring displacement of the horizontal lines, causing vertical picture elements, picture edges, and reticle marks to have a wavering or scalloped appearance. A similar but less severe displacement of the vertical picture elements, is also present and there is an intensity modulation of the raster which results in the appearance of alternate dark and light horizontal bars of uniform dimension. All of these modulations occurred at a frequency of 33 cycles per TV frame. This is equivalent to 0.165 cps (the APT frame is scanned in 200 seconds), which is identical to the satellite's spin rate of 10 rpm.

It was hypothesized and confirmed by tests at AED using the F-1 APT camera that these modulations could result from the earth's magnetic field deflecting the electron beam in the APT vidicon as the satellite rotated. Further confirmation of this hypothesis was obtained by correlating the severity of the modulations with satellite attitude. When the satellite was in such an attitude as to align the earth's magnetic flux lines with the camera axis, the problem was at a minimum (Figure V-7). When the angle between the camera axis and the flux lines was approximately 40 degrees, the problem was most severe (Figure V-8). At angles above 40 degrees, the severity of the deflections did not appear to increase. Although some video data was lost as the result of this problem, to a considerable extent these modulations distorted rather than destroyed the video data and since they occurred at a uniform rate, it was possible to undertake correction of the video signals. Two devices, one electromechanical and the other electronic, were designed and tested at AED to counteract this problem. These devices were investigated for use in APT picture correction but were not placed in service due to the brief remaining span of orbital life of the APT subsystem.

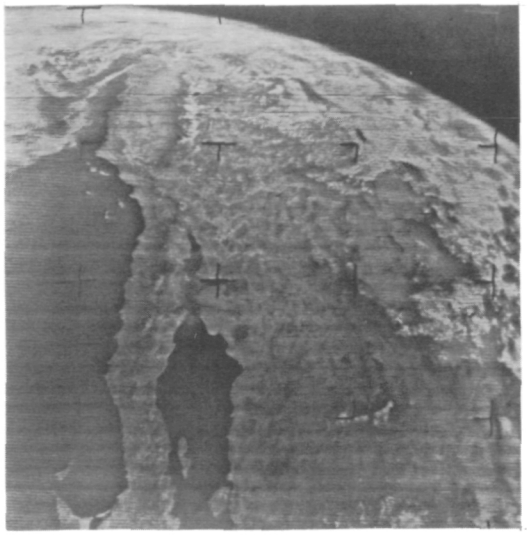


Figure V-7. Example of Least Severe APT Picture Distortion

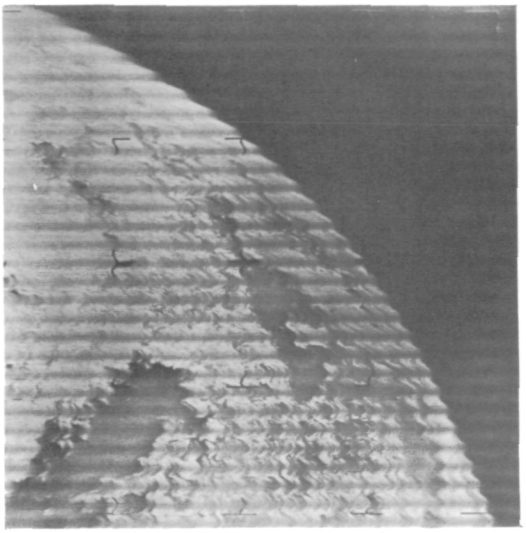


Figure V-8. Example of Severest APT Picture Distortion

The electromechanical device provided the means for correcting both the horizontal and the vertical error. The 2400 cps APT video subcarrier was used as excitation for a resolver. The phase of the output of the resolver referenced to its input was of course determined by the position of the rotor, the phase modulation being proportional to the rotation of the resolver shaft. Since the error was sinusoidal (at a frequency of about 1/6 cps), the rate of change of shaft rotation was also sinusoidal. This motion was obtained from a DC motor, a scotch yoke, and a rack and pinion.

The frequency and phase of the correction was controlled by a phase-locked loop. The elements in the loop were a 1/6 cps detector, a DC motor and motor drive circuits, and a phase detector. The 1/6 cps detector detected the error signal in the video which was used as the reference signal.

A signal was also derived from the shaft of the motor by means of a cam and microswitch. The reference signal and the signal derived from the shaft were compared in the phase detector and the motor drive was varied to obtain the correct phase relationship to drive the facsimile machine.

The vertical correction was obtained by moving the blade of the facsimile machine sinusoidally about its normal position. The amplitude and phase were adjusted by a cam mechanism.

In the electronic device, the phase modulation was produced by generating a 120-cps ramp synchronized with the output of the facsimile recorder. The

ramp signal was mixed with the 1/6 cps correction signal and the resultant signal drove a Schmitt trigger circuit. The modulated signal was connected to the 120 pps playback input of the facsimile machine.

The intensity correction was provided by a variable gain amplifier. The control of the gain was provided by the same detected 1/6 cps signal which was used to modulate the phase of the 120 pps signal.

The vertical displacement error was not reduced with the electronic system. This machine did not therefore remove the error in location of cloud or ground objects in the vertical direction (on the order of one to two percent).

A second problem in the APT camera was a gradual loss of contrast. This problem eventually led to the cessation of programming of subsystem No. 2 in late May 1964. The symptom of this problem was a video signal for some frames that almost completely exceeded the white reference. The brightness level in the pictures appeared to vary. This problem was attributed to degradation of the vidicon tube.

c. APT Video Transmitter

The performance of the 5-watt APT video transmitter was excellent. Signal strengths of from 3 to 5 microvolts were present at the ground station receiving antennas at maximum satellite range and no signal fading problems were experienced.

4. Ground Station Components

The ground station components of the TIROS VIII TV picture subsystem performed satisfactorily, requiring only routine adjustment and repair. Operation of the ground station equipment is discussed in Section XIII.

The APT RF link between TIROS VIII and the APT station was entirely adequate. Signals of 3 to 5 microvolts were normally experienced at the output of the antenna.

Some types of interference were noted between other systems on the satellite and the APT camera. Except for interference which occurred when the TIROS camera TV transmitter was operating, most of the interference was caused by microphonics rather than electrical interference. The most objectionable of this interference was that caused by the telemetry switches. The AED APT station did not experience any interference from local sources.

A comparison was made of three different models of facsimile machines for recording the APT video. These were the Fairchild Camera and Instrument electrolytic paper recorder, supplied as part of the station built by Fairchild Stratos; the Muirhead electrolytic paper recorder, used extensively in the ground checkout equipment for the Nimbus APT system; and the Muirhead Photofax recorder which is a modified version of the Muirhead wirephoto machine. The Muirhead photofax recorder gives the most pleasing gray scale reproduction and the best contrast range of the three machines. The photographic process that is used to develop the picture also permits some adjustment in order to improve picture quality.

The Muirhead Photofax machine has two drawbacks in an application such as that of TIROS APT picture recording. The first of these is that the paper is loaded into a cartridge which must be changed for each new picture. It is not possible to change cartridges in the time available between APT pictures. The second drawback is typical of any photographic type of machine; it is not possible to see the picture as it is being transmitted. This is undesirable because it prevents using the simple method of observing the time that the rows of fiducial marks appear in order to determine the time at which the picture was taken.

VI. INSTRUMENTATION—CONTROL SUBSYSTEM

A. FUNCTION

The instrumentation-control subsystem consisted of the satellite and ground station components required for control of satellite operations by the Command and Data Acquisition (CDA) ground stations. The ground station components of the control subsystem consisted basically of programming units for generating coded commands for specific satellite functions, and communications equipment for modulating and transmitting the command messages to the satellite. Because of the limited duration of each communications contact between a ground station and the satellite, and because part of this time was consumed in receiving data from the satellite, timing equipment was also necessary so that the command messages could be selected in advance of a contact and then generated and transmitted in sequence at preset alarm times. The satellite commands were of two fundamental types: (1) discrete commands to which a satellite circuit made an immediate single response (e.g., fire spin-up rockets) and (2) programs that were stored by the satellite circuits and used to control delay timing and picture taking while the satellite was beyond communications range of a ground station. The CDA ground station equipment also included components for automatic satellite tracking and for programmed satellite tracking during the satellite-to-ground radio contact.

The satellite instrumentation-control subsystem included communications receiving equipment to receive and demodulate the commands, control circuits which separated the commands and initiated the individual command functions, and storage and counting (clock) circuits which stored remote programs and synchronized and controlled the sequence of operations of the TV cameras, tape recorder, and transmitters. A command address unit in the TIROS VIII satellite control subsystem prevented the satellite from responding to transmissions intended for other TIROS satellites or to any other transmissions that approximated the command signals. (Both TIROS VI and VII were still being commanded and interrogated at the time of the TIROS VIII launch.)

Each command to the satellite was preceded by the TIROS VIII coded address.

The satellite functions that were controlled by ground command were as follows:

(1) Operation of the TV camera subsystems in the direct mode of operation and programming of the satellite clocks for control of remote camera operation.

(2) Readout (playback) of stored camera subsystem No. 1 TV video and sun-angle data.

(3) Telemetry readout.

(4) Beacon "kill" and turn-on.

(5) Magnetic attitude control.

(6) Firing of spin-up rockets.

(7) Backup of de-spin mechanism and precession damper operation (both are normally initiated automatically at separation from the third-stage rocket).

The ground-station components of the instrumentation control subsystem included command programmers, control-tone generators, remote-picture time-set units, clock-set pulse demodulators, a program selector and power control unit, a command transmitter, antenna programmer, a WWV receiver, a master clock, an alarm unit, and power supplies. The satellite components of the subsystem were two command receivers, two camera-control units, an auxiliary-control unit, two timing and sequencing (clock) units, a magnetic attitude control circuit, a rocket firing control circuit, a beacon turn-off control circuit, and two 1.5-year timers. Details concerning operation of the components, the modes of operation, the program sequences, and the command functions are described in detail in the TIROS VIII final engineering report.

B. PERFORMANCE EVALUATION

The performance of the TIROS VIII instrumentation control subsystem was generally very good during the period covered in this report. However, in the initial period of orbital operation of TIROS VIII, it was noted that programmed remote picture sequences frequently did not begin at the exact times contained in the command messages transmitted to the satellite by the CDA stations. Discrepancies were observed that ranged from a few seconds to complete orbit periods and some programmed remote sequences did not occur at all, presumably

because the actual delay period exceeded the orbit period and the satellite was reprogrammed for a succeeding orbit before the previously programmed sequence could begin. In the early months of TIROS VIII operation fewer than 50 percent of the programmed remote sequences started exactly on time, although many were in error by only a few seconds.

This problem appeared to be similar and perhaps identical to a problem of inaccurate alarming of the satellite's remote timing clocks that had occurred on the TIROS VII satellite. A broad investigation of this problem, including evaluation tests of both of the active satellites, was conducted by AED evaluation engineers. This investigation included satellite command sensitivity tests of TIROS VII, special programming tests of both satellites, antenna pattern tests of TIROS VII, studies of effects of the aurora borealis at the Alaska ground station, and waveshape measurements of the clock-set pulses transmitted to both satellites. Although these tests did reveal some differences in the characteristics of the clock-set pulse detection circuitry of the two satellites, and, although the auroral effects were shown to have an undeniable effect on satellite transmissions and, by inference, on command reception, the major source of the clock-setting problem was eventually traced to the performance of the ground station equipment. The clock-set pulses transmitted to the satellites were found to vary in waveshape from pulse to pulse; some pulses were deficient in amplitude or duration or both. As a consequence, some pulses transmitted to the satellites were apparently rejected by the satellite detection circuits which, to prevent responses to spurious pulses, are designed and adjusted to accept only those pulses that exceed preset amplitude and duration thresholds. Each valid pulse that is rejected accounts for a two-second error in clock-set alarm time.

A secondary problem was also recognized which could account for the instances when large numbers of clock set pulses were lost. The transmission of clock-set pulses to the satellite, in a typical command and data acquisition contact, is time-shared with the transmission of a playback enable tone, which causes the satellite to play back recorded picture data and also maintains the command receiving and detecting circuits in an enabled condition, so that the clock set pulses and the enable tone continue to be received and detected. If this enable tone is interrupted for more than a specified period of time, these circuits become automatically disabled and the command procedure (including the satellite address) must be reinitiated before the satellite will accept additional commands. The poor condition of the clock-set pulses could account for the loss of the time-shared enable tone in the interpulse periods, which, in turn, could prevent the reception of additional clock-set pulses. Since picture delay time increases inversely with the number of clock-set pulses detected by the satellite, this process could account for the extreme deviations in clock-setting accuracy, including those instances in which the clocks apparently did not alarm at all.

To eliminate these problems, the performance of the ground station command equipment was improved to provide uniform pulses of proper duration and amplitude. Also, a revised format was developed for transmitting the clock-set pulses to the satellite to ensure that the enable tone could not be interrupted for a period long enough to result in command dropout. This was accomplished by dividing the clock-set pulses into groups for transmission. The duration of a group was short enough so that a command dropout could not occur during its transmission. Between the groups, a sufficient duration of the playback enable tone was transmitted to ensure continued operation of the detection circuits.

In addition to these changes, provisions were made at each ground station for visually monitoring the clock-set pulse modulation waveforms using a TIROS (satellite) command receiver and an oscilloscope to ensure that the waveshapes reaching the satellite detection circuits were of proper shape and duration.

These changes, which were implemented in March, 1964, brought about an immediate improvement in clock-setting performance. The percentage of precisely accurate clock alarms increased from 45.3 in February of 1964 to 71.2 in March. For April, the first full month during which the changes were in effect, the percentage of "on-time" alarms increased still further, to 87.5 percent. Clock-set performance continued at a uniformly high level thereafter throughout the period evaluated in this report.

The sensitivity tests, auroral studies, antenna pattern tests, special programming tests, and waveform measurements performed in connection with this investigation are described in the TIROS VII evaluation report. The auroral studies, the special programming tests, and the measurements of transmitted set pulse waveforms are equally applicable to TIROS VIII evaluation and reference should be made to the discussions in the TIROS VII evaluation report for more information concerning these areas of the investigation.

VII. TELEMETRY AND TRACKING SUBSYSTEMS

A. FUNCTION

The TIROS VIII satellite telemetry and tracking subsystem consisted of two 50-milliwatt beacon transmitters and two identical 40-point telemetry circuits. The ground station telemetry equipment consisted of diversity-connected beacon receivers and telemetry demodulating and recording equipment. The satellite was equipped with two beacon timers, each of which was designed to turn off both beacon transmitters at the end of a 1.5 year period of operation in orbit.

The 50-milliwatt beacon transmitters operated continuously throughout each orbit with the exceptions that they could be temporarily turned off by the beacon "kill" command, and Beacon No. 1 was automatically disabled while the APT subsystem was transmitting.

During the greater portion of the orbit, while the satellite was not in contact with a CDA ground station, the beacon transmitters were amplitude modulated by the attitude data. Stations of the NASA Minitrack network tracked the satellite to obtain position information so that ephemeris data could be prepared for the CDA stations. When the satellite was interrogated by a CDA ground station, a telemetry readout was automatically initiated, displacing the attitude data for a period of 32 seconds. The 39 telemetry points were sampled and the telemetry voltages, in sequence, were frequency modulated on a subcarrier. The subcarrier was amplitude modulated on the beacon carrier and transmitted.

A telemetry readout could also be initiated separately from playback or direct operation of the satellite's camera subsystems by an emergency telemetry command transmitted by the ground station.

Each telemetry circuit consisted of a 40-position electro-mechanical commutator switch, a voltage-controlled subcarrier oscillator (SCO) operating at a center frequency of 1300 cycles per second, and various temperature, voltage, and current sensing networks. Thirty-three of the telemetry points were operating parameters, six were calibration voltages, and the 40th (or 0) position of the switch was a "home" position. Of the 39 active telemetry points sampled by each telemetry commutator, 24 that pertained to overall satellite operation were identical in each half of the subsystem, to ensure that the loss of data from one of the beacons would not mean total loss of telemetry data.

When a telemetry-sampling cycle was initiated, the telemetry commutator stepped through its 40 positions, remaining at each of the 39 positions for 0.8 second and then stopping at the 40th (home) position. At each sampling point, the voltage generated by the sensing device was applied through commutator contacts to the SCO, causing a shift in the SCO frequency output proportional to the voltage at that point. The upper and lower limits of the d-c voltages from the sensing devices were +2.5 volts and -2.5 volts, corresponding to SCO frequency shifts of +100 and -100 cps around the 1300-cps center frequency. The output of the SCO amplitude-modulated the associated beacon transmitter for transmission of the telemetry data to the interrogating ground station. The telemetered parameters and their assigned telemetry channels are given in Table VII-1.

At the ground station, the beacon transmissions were received by two R390A receivers connected in polarization diversity combination. The telemetry data was demodulated by a Sanborn Model 150-2800 preamplifier and was recorded by pen on a strip chart by a Sanborn Model 152-100B recorder. The satellite-borne and the ground-based components of the subsystem were designed to provide an overall data accuracy of ± 5 percent of full scale deflection on the Sanborn recorder.

The position of the attitude-control switch, which is indicative of the amount and direction of current in the magnetic bias control (MBC) coil, could be read out and transmitted to the ground at any time except during telemetry transmission upon command from the interrogating CDA station. If the request for MBC switch position data was made while camera subsystem No. 1 was in use, the data was transmitted by beacon transmitter No. 1; if camera subsystem No. 2 was in use when the request was made, the data was transmitted by beacon transmitter No. 2. Since only one beacon transmitter was used for sending the switch-position data to the CDA station, the other was free to continue sending uninterrupted attitude data.

Because the frequency of beacon transmitter No. 1 (136.92 Mc) was very close to that of the APT transmitter (136.95 Mc), simultaneous operation of both transmitters might result in intermodulation. Therefore, a modification was incorporated in the TIROS VIII telemetry and tracking subsystem which automatically turned off beacon transmitter No. 1 whenever the APT transmitter was in operation.

TABLE VII-1. TELEMETERED PARAMETERS OF THE TIROS VIII SATELLITE

Telemetry Switch Position No.	Parameter Beacon No. 1 (136.92 Mc)	Parameter Beacon No. 2 (136.23 Mc)
1	Calibration: Zero Volts	Calibration: Zero Volts
2	Calibration: -0.5 Volts	Calibration: - 0.5 Volts
3	Calibration: -1.0 Volts	Calibration: -1.0 Volts
4	Calibration: -1.5 Volts	Calibration: -1.5 Volts
5	Calibration: -2.0 Volts	Calibration: -2.0 Volts
6	Calibration: -2.5 Volts	Calibration: -2.5 Volts
7	"X" String Battery Output: -28 Volts	"X" String Battery Output: -28 Volts
8	"Y" String Battery Output: -28 Volts	"Y" String Battery Output: -28 Volts
9	"Z" String Battery Output: -28 Volts	"Z" String Battery Output: -28 Volts
10	Main Load Bus: -28 Volts	Main Load Bus: -28 Volts
11	Regulated -24.5 Volts, System No. 1	Regulated -24.5 Volts, System No. 1
12	Regulated -24.5 Volts, System No. 2	Regulated -24.5 Volts, System No. 2
13	Regulated -13.0 Volts, System No. 1	Regulated -13.0 Volts, System No. 1
14	Regulated -13.0 Volts, System No. 2	Regulated -13.0 Volts, System No. 2
15	TV Xmtr Power Converter, System No. 1	Clock No. 1, 0.5 pps
16	TV Xmtr Drive Voltage, System No. 1	Clock No. 2, 0.5 pps
17	Vidicon High Voltage, System No. 1	Solar Cell Patch Output Voltage
18	Filament and Focus Current, Vidicon No. 1	APT Mode Indicator
19	500-cps Converter for Tape Recorder No. 1	Temperature, Base at 300° Location*
20	"Home" Position of Rocket Switch	Temperature, Inner Top Skin, at 3" radius*
21	Solar Cell Patch Output Voltage	Temperature, Inner Top Skin, at 12" radius*
22	APT Mode Indicator	Temperature, Side Panel at 30° Location*
23	Temperature, TV Xmtr No. 1‡	Temperature, Solar Cells at 3" radius*
24	Temperature, APT Xmtr*	Temperature, 1.5-year Timer†
25	Temperature, Horizon Scanner‡	Tuning Fork Oscillator 1 or 2 -
26	Temperature, Clock No. 2‡	2400 cps Indicator -
27	Temperature, Camera No. 2‡	G1 Voltage -
28	Temperature, Battery Pack‡	Focus Current -
29	Temperature, 1.5-year Timer ‡	Vicidon Filament Current -
30	Temperature, Base at 300° Location‡	Horiz. and Vert. Defl. -
31	Temperature, Base at 300° Location‡	Xmtr. Converter Lo-Volt. -
32	Temperature, Base at 300° Location*	Xmtr Converter Hi-Volt. -
33	Temperature, Inner Top Skin, at 3" radius*	-6.3 Regulator Voltage -
34	Temperature, Inner Top Skin, at 12" radius*	Output, Video Modulator -
35	Temperature, Side Panel at 30° Location*	Xmtr RF Drive -
36	Temperature, Solar Cells at 3" radius*	Temperature: Focus Current Regulator - (Special Range)
37	Clock No. 1, 250 pps	Temperature: Vidicon Target - (Special Range)
38	Clock No. 1, 0.5 pps	Temperature: Power Supply (Special Range) -
39	Clock No. 2, 0.5 pps	Temperature: Xmtr No. 2* -
40	Home (Reset to Horizon Scanner Data)	Home (Reset to Horizon Scanner Data)

APT Camera System Measurements

*Temperature Sensor Range: -30 to +100°C
‡Temperature Sensor Range: 0 to +40°C
† Temperature Sensor Range: -70 to +10°C

B. PERFORMANCE EVALUATION

1. General

The beacon transmitters operated reliably throughout the 24-month period of evaluation. Beacon signal strengths as received by the CDA stations and Minitrack stations were normal on all occasions. Beacon signal-strength data compiled by the CDA stations indicated that beacon RF power was greater than the 50-mw minimum required by specification. Telemetry operation of the high-frequency (No. 1) portion of the subsystem was normal during the entire evaluation period. The high consistency and correlation of the telemetry data from beacon No. 1 indicated normal operation of the subcarrier oscillator circuit; ground station chart recordings of the telemetry data also showed that the stepping rate of the telemetry commutator switch was normal. Telemetry operation on the low beacon frequency (136.23 Mc) was also normal in all respects until orbit 331, when the commutator switch malfunctioned, preventing its further use. Loss of telemetry data was minimized because of subsystem redundancy (24 of the 39 points were identical in both portions of the subsystem).

The 18-month timers included in the telemetry and tracking subsystem to turn off the beacon transmitters did not operate.

2. Malfunction of Beacon No. 2 Telemetry Commutator

On January 13, 1964, (orbit 331), TIROS VIII was routinely interrogated by the CDA ground station. The telemetry readout started normally at the beginning of the interrogation and progressed until the telemetry switch associated with the low-frequency beacon (No. 2) reached position 4, where, as indicated by the ground station telemetry recording, it stopped and remained. During subsequent interrogations on orbits 331 through 336, emergency telemetry was commanded in an attempt to cause the switch to advance. However, the switch could not be moved from position 4.

During these same interrogations, telemetry from the high-frequency beacon (No. 1) indicated that satellite battery voltage was decreasing and that the voltages at telemetry points 1, 2, 3, 4, 9, 10, 11, and 13 were also decreasing steadily. However, at the same time, the operation of the subsystems in which these telemetry points were located showed no indication of abnormal performance, suggesting that the telemetry readings were in error.

A telemetry readout commanded on orbit 343 showed that the telemetry switch was still resting at position 4. However, telemetry data from the high-frequency beacon indicated that the battery voltage had returned to normal. The

voltages at telemetry positions 1, 2, 3, 4, 9, 10, 11, and 13 were at zero. Operation of the subsystems in which there points were located continued to be normal. Further telemetry readouts confirmed that the condition had stabilized, with the battery voltage restored to normal and with all other subsystems functioning normally, but with the loss of No. 2 telemetry and of useful data from eight of the telemetry points.

From the immediate and progressive decrease in battery voltage that accompanied the telemetry switch malfunction, it was apparent that a continuous high current drain was associated with the malfunction. The sudden return of the battery voltage to a normal level sometime between orbit 336 and 343 suggested that the low resistance path which caused the high current drain had deteriorated and become an open circuit. Because the eight telemetry voltages did not return to normal with the battery voltage, and because all other subsystems operated normally, it can be assumed that these points had been irrevocably damaged by the malfunction, as had the telemetry switch or its drive circuit. Since the voltages at these eight telemetry points all reached ground level, it was probable that the points were short-circuited to ground.

The telemetry switch drive circuit was analyzed theoretically to determine the possible causes of a high current drain that could result in the observed conditions. The circuit is shown in schematic form in Figure VII-1. Five possible failure modes were noted, as follows:

(1) A low-resistance path between the -26 volt lead and the ground return lead.

(2) A low-resistance path through capacitor C2.

(3) Transistor Q1 permanently turned on by a constant forward bias on its base-to-emitter junction.

(4) A high collector-to-emitter leakage current in transistor Q1.

(5) A high collector-to-emitter leakage current in transistor Q2.

These failure modes were analyzed for their relative probability. The first, a low resistance between the supply voltage lead and the ground return lead in the drive circuit, seemed very improbable since the circuit had operated normally for 330 orbits without excessive current drain and there was no known mechanism of vibration or wear to cause deterioriation of the insulation on these leads in orbit. Furthermore, a short circuit of this nature would probably not have persisted for a period of five orbits.

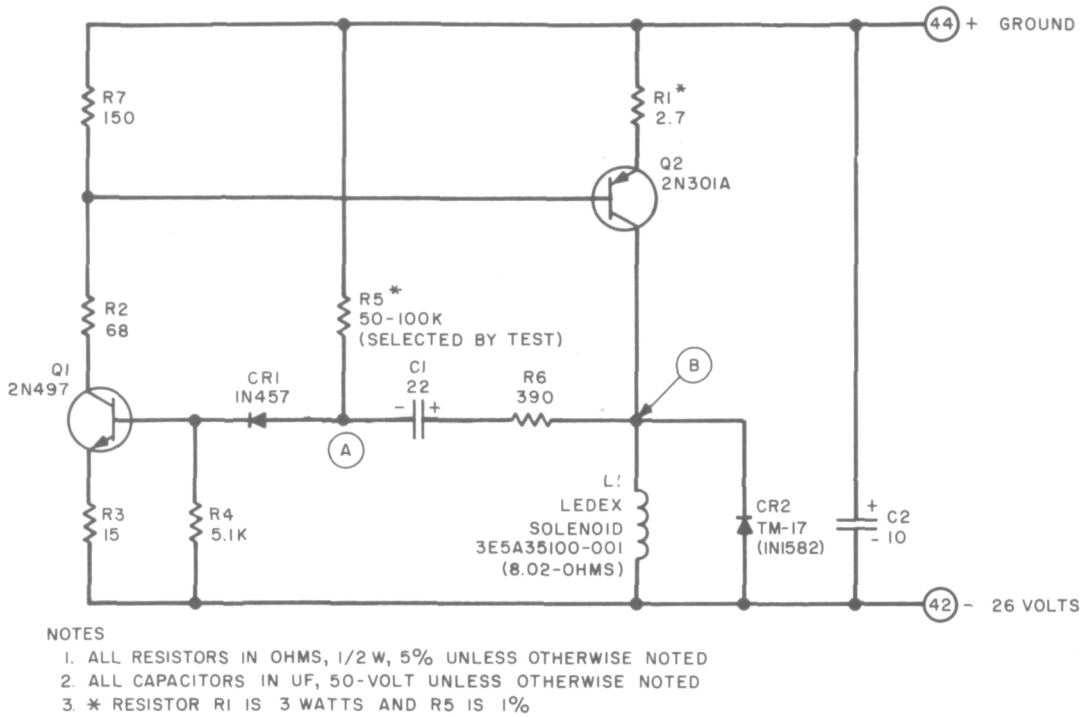


Figure VII-1. Schematic Diagram of Telemetry Switch Drive Circuit

The second failure mode also seemed highly improbable, since capacitors of the type used at C2 usually fail by gradually decreasing in capacitance rather than in resistance.

The third failure mode was rejected because, in order for Q1 to have a constant drive on its base, it would be necessary for C1 to short circuit while transistor Q2 was conducting. (IF C1 shorted while Q2 was not conducting, Q2 would remain non-conducting and very little current would flow in the circuit.) As with C2, capacitor C1 is of the type that deteriorates by decreasing its capacitance rather than its resistance. If the capacitance of C1 had decreased, the stepping rate of the telemetry switch would have increased, which was not observed. If, as an extreme, C1 had become open-circuited, the voltage divider comprising resistors R4 and R5 would have kept Q1 turned off permanently.

The fourth failure mode examined was a high collector-to-emitter leakage (short-circuit) of Q1, which could cause Q2 to become forward biased and would result in a high current drain by the circuit. (The magnitude of the current would be limited by the series resistance of R1 and solenoid L1 to about 2.5 amperes.) A failure of Q1 could have been caused by degradation of the transistor or by damage to the transistor as a result of resistor R4 becoming open or of diode CR1 becoming shorted. If R4 had opened while both transistors were conducting, all the charging current through C1 would have passed through

the base-to-emitter junction of Q1, and would probably have caused this junction to develop a short. If CR1 shorted, the voltage transient at point A in Figure VII-1, when Q2 was cut off, could cause the base-to-emitter junction of Q1 to break down in the reverse direction, resulting in a collector-to-emitter punch-through. This latter probability, however, was discounted in testing when shorting CR1 did not damage Q1 but instead increased the telemetry switch stepping rate. Also, in the presence of a high voltage transient, CR1 would probably open before Q1 could be damaged.

The last failure mode considered was a high collector-to-emitter leakage or short circuit in transistor Q2. Here again, the maximum current would be limited by the resistance of R1 and L1 and the actual current would be determined by the amount of leakage through Q2. Transistor Q2 could have degraded or could have been damaged by a large power supply current transient (while Q2 was conducting), or by diode CR2 becoming open circuited. If CR2 had opened, the voltage transient generated when solenoid L1 deenergized would probably have caused a collector-to-emitter breakdown of Q2 in the reverse direction. Since the possibility of two simultaneous but independent component failures was small, this situation was not investigated.

On the basis of this theoretical analysis of the telemetry drive circuit, the most probable cause of the initial failure condition was a high leakage current in transistor Q2.

Following the theoretical analysis, the investigation of this problem was continued with electrical testing of the drive circuit. It was found that a power supply voltage in excess of 60 volts would consistently induce failure of transistor Q2, causing the transistor to draw excessive current. (The normal power supply voltage is -26 volts.) Although it is not possible to prove that Q2 failed on TIROS VIII, it is believed to be the most probable cause of the switch malfunction.

Further testing was conducted to observe if the other conditions which followed the initial failure could be simulated. For this test, a spare telemetry switch (serial number 122) was obtained. An over-voltage of 90 volts was applied briefly to the drive circuit to induce initial failure. Afterward, the supply voltage was reduced to the normal value of -26 volts. The drive circuit drew a steady current of 1.5 amperes.

A dummy harness was connected to the test switch and a zener diode was mounted at the top of the switch to simulate the TIROS VIII configuration. The switch was mounted on a heat sink to simulate attachment to the TIROS VIII baseplate. Temperature sensors were mounted on the heat sink, on top of the switch (opposite pin 4), and on the rear of the switch. The entire test setup was placed inside a bell jar in which a simulated baseplate temperature of between 65 and 70°F was

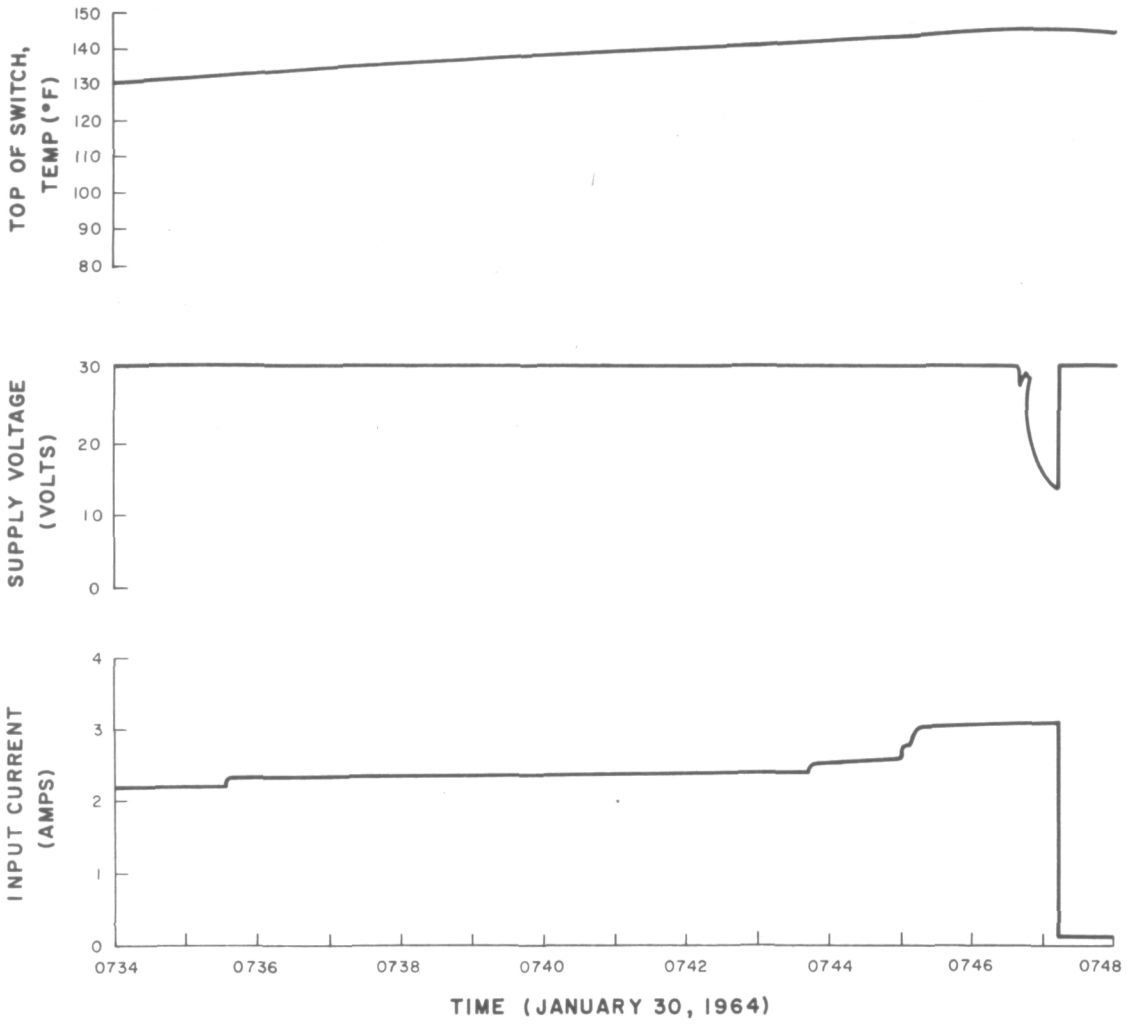


Figure VII-2. Test Telemetry Switch Parameters Immediately Before and At Failure

maintained during testing. A summary of the test and a listing of the results are given in Table VII-2.

The test began at 1200 hours on January 29, 1964. The test telemetry switch failed at approximately 0747 hours on January 30, 19 hours and 47 minutes after the start of the test. Figure VII-2 shows curves of the input current, supply voltage, and top temperature of the test switch at one-minute intervals between 0734 hours and 0748 hours on January 30. The top temperature of the switch increased linearly with time from 132°F at 0734 hours to 146°F at the time of switch failure. The supply voltage remained constant at approximately 30 volts until the switch began to draw heavy current (approximately 3.1 amperes); then, as the power supply (which was rated at 2.5 amperes) began to limit, the supply voltage decreased to 14 volts for approximately 35 seconds. When the switch

TABLE VII-2. LABORATORY TEST ON TELEMETRY SWITCH

Time and Date	Action	Result	Input Current (amps)	Temperature (°F)	
				Top	Side
1/29/64					
1200	Start pumpdown	----------			
1430	26 VDC applied to switch	----------			
1520	----------	Switch internal temperture increased to 105°F and switch began to operate. Temperature fell to 75°F.	----------		
1540	Input voltage increased to 28 VDC	Switch locked up and drew current. Internal temperature increased to 113°F.	1.5		
1650	----------	Switch resumed operation.			
1651	Input voltage increased to 30 VDC and held at this value through the remainder of this test.	Switch locked up and continued to draw current throughout the remainder of this test.	1.5		
1710			1.55	104	110
1730			1.55	117	122
1800			1.7	122	123
1830			1.7	123	125

TABLE VII-2. LABORATORY TEST ON TELEMETRY SWITCH (Continued)

Time and Date	Action	Result	Input Current (amps)	Temperature (°F)	
				Top	Side
1900			1.7	123	126
1930			1.65	124	127
2000			1.65	123	127
2030			1.65	124	125
2100			1.7	123	125
2130			1.7	122	125
2200			1.75	122	124
2230			1.85	123	125
2300			1.85	125	128
2330			1.8	125	127
2400			1.8	125	127
1/30/64					
0030			1.8	124	127
0100			1.8	124	127
0130			1.8	125	129
0200			1.9	125	129
0230			1.9	125	129

TABLE VII-2. LABORATORY TEST ON TELEMETRY SWITCH (Continued)

Time and Date	Action	Result	Input Current (amps)	Temperature (°F)	
				Top	Side
0300			1.9	125	130
0330			1.9	126	130
0400			1.9	127	130
0430			2.05	129	132
0500			2.0	130	132
0530			2.05	130	132
0600			2.1	130	133
0630			2.0	131	132
0700			2.2	133	135
0730			2.2	133	135
0830	Vacuum broken and test switch removed.				

failed (approximately 0747 hours) the supply voltage immediately increased to the original value of 30 volts. (This limiting would not have occurred on the satellite since the power source was the battery pack.)

The test switch was removed from the bell jar and examined. No damage to any of the leads in the test harness was found. A resistance check between each pin and circuit ground on the switch housing indicated a low resistance (less than 100 ohms) on three pins.

The hermetically sealed telemetry switch enclosure was opened and the circuit board and inside surfaces of the enclosure were examined. The circuit board was badly charred in the vicinity of R1 (Figure VII-1). Capacitor C1 had exploded and its outer casing was lying on the bottom of the switch enclosure. Resistor R3, which had been mounted beside C1, was also lying loose on the bottom of the switch enclosure. Resistor R1 was charred and one lead had become unsoldered. A d-c resistance test was performed on the transistors; Q1 was normal, but Q2 had a low collector-to-emitter resistance.

Material from the charred circuit board and components was found on top of the switch enclosure. This deposit formed the low resistance paths to ground for the three telemetry switch receptacle pins mentioned previously.

From the data obtained during the test and from observations and tests on the test telemetry switch, it would appear that the following sequence of events caused the destruction of the telemetry switch under test:

> From January 29 at 1730 hours until January 30 at 0735 hours, the input current and switch temperature increased slowly. This increase was probably caused by an action somewhat like thermal runaway. The excessive current flowing through R1, Q2, and L1 in the drive circuit caused the temperature inside the switch to increase. The increased temperature further degraded the emitter-to-collector junction of transistor Q2, causing a further current increase. This progressive action continued with both temperature and current increasing. The current rapidly increased from 2.2 to 2.35 amperes between 0735 and 0736 hours, then gradually increased to 2.4 amperes at 0743 hours. The resulting increase in heat degraded Q2 further and probably also damaged resistor R1.
>
> Since capacitor C1 was physically located close to R1, the heat generated by high current flow in R1 (3.1 amperes at 0746 hours) probably caused the electrolyte in C1 to expand until C1 exploded. The force of the explosion dislodged R3 from the circuit board and broke one end of R1 loose, thus breaking the primary current path through the circuit.

The electrolyte from C1, the potting material on the circuit board, and sections of the board were probably vaporized by the explosion and formed the deposits found on top of the switch. The small current drain after the capacitor had exploded was caused by the low resistance path of the deposited material.

Telemetry data from the TIROS VIII satellite indicated that the malfunctioning telemetry switch drew excessive current for several orbits and then ceased drawing current at some time between 10 and 18 hours later. The telemetry switch tested in the laboratory failed 14.25 hours after it had stopped stepping. The external responses of the TIROS VIII switch and the test switch were very similar and it is probable that the two failed by the same mechanism. The cause of the original malfunction (i.e., continuous conduction) is uncertain. A transient of greater than 60 volts was required to cause the test switch to malfunction initially in the laboratory.

The loss of the telemetry calibration voltage at telemetry point 4 on TIROS VIII could have been caused by deposits formed by vaporized electrolyte (from capacitor C1) on top of the switch, as happened in the test. The rotating contact of the telemetry switch commutator is connected to pin 41, which is almost directly above capacitor C1. The vaporized electrolyte could have caused a low impedance path between pin 41 and ground. On TIROS VIII, the commutator stopped at position 4 and a sufficiently low impedance from pin 41 to switch position 4 could have resulted in the loss of the calibration voltage.

It is improbable that the apparent low impedance paths between pins 1, 2, 3, 9, 10, 11, and 13 and ground on the TIROS VIII switch were caused by deposits of vaporized electrolyte, since no orientation of the circuit board with respect to the feed-through terminals would place the charred sections of the board under these pins. It is possible that the insulation on the leads that connect the commutator disk to the terminals might have been damaged by heat. On the test switch these leads were not in contact with the mounting block. However, the lead dress is not the same in each unit.

In summary, the investigation revealed the following facts:

(1) The initial cause of the TIROS VIII telemetry switch malfunction, in which the switch stopped operating and drew a continuous heavy current, is uncertain. However, it is probable that a collector-to-emitter breakdown of transistor Q2 took place.

(2) The destruction of capacitor C1 by heat generated in resistor R1 as a result of excessive current flow was the most probable cause for the telemetry drive circuit to open and the heavy current drain to stop.

(3) One telemetry point (position 4) was very probably shorted to ground by vaporized electrolyte from the explosion of capacitor C1.

(4) The remaining telemetry points that ceased providing data may have been shorted to ground by insulation damage and/or by a coating of the vaporized electrolyte from capacitor C1.

VIII. REFERENCE–INDICATOR SUBSYSTEM

A. INTRODUCTION

The attitude-indicator subsystem and the north-indicator subsystem are referred to collectively as the "reference-indicator subsystems." These subsystems, respectively, provided reference data from which the satellite attitude could be determined and orientation of cloud-cover photographs taken by camera subsystem No. 1 could be determined. The attitude-indicator subsystem provided an indication of the satellite spin-axis attitude with respect to the earth while the north-indicator subsystem provided data from which satellite's orientation with respect to satellite-sun line at the instant of taking subsystem No. 1 TV pictures could be determined. Attitude data was essential in planning future picture taking and power expenditure since the attitude of the satellite determined where in the orbit the cameras would point at the earth, whether the earth area viewed by the cameras would be illuminated, and how much power would be available from the satellite's solar energy converter for satellite operations. The north-indicator subsystem, by supplying data that gave the satellite's angular orientation with respect to the sun at the instant of each camera No. 1 exposure, made it possible, by correlation with ephemeris data, to determine the geographic directions in the TIROS pictures. The spin rate of the satellite could also be derived from the data supplied by either of these subsystems.

The reference-indicator subsystems on TIROS VIII were identical to their counterparts on TIROS VII. However, the incorporation of the APT subsystem (camera subsystem No. 2) in TIROS VIII created a requirement for an additional method of picture orientation, since most APT pictures were transmitted outside communication range of the CDA stations and the APT ground stations did not include computing equipment such as that used at the CDA station to derive picture orientation. As described later in this section, the output from one of the sun sensors in the north-indicator subsystem was used to trigger the APT camera and provide the needed reference for picture orientation.

B. FUNCTION

1. Attitude-Indicator Subsystem

The attitude-indicator subsystem provided data to the ground stations from which the attitude of the satellite's spin axis could be computed. The data was derived from the output of an infrared sensor, fixed on the satellite's baseplate,

which alternately scanned the earth and space as the satellite rotated. Heat radiation from the earth caused an electrical output pulse from the sensor during the period in which it scanned the earth. This pulse was differentiated and amplified, and then applied as a modulating signal to the telemetry subcarrier oscillators for transmission by the beacon transmitters to the CDA ground stations. Transmission of the attitude information was continuous except when interrupted for 40 seconds at the beginning of each ground station interrogation for sending of telemetry data.

The attitude-indicator subsystem consisted basically of a narrow-field, infrared-sensing bolometer and an amplifying and differentiating circuit. The sensor had a 1.2 by 1.2 degree square field of view, and it was mounted with its optical axis at an angle of 70 degrees, 7 minutes to the top of the spin axis of the satellite. The sensor had a time constant of 2.0 milliseconds, and a spectral response between 7 and 30 microns, which fell off sharply at wavelengths shorter then 7 microns. The spectral response and time constant were chosen so that uniform and accurate response occurred whenever the field-of-view included the earth; the sensor was oriented in such a manner that during the operating period it would never view the sun directly if attitude variations were of the type predicted. Although no damage would result if the sensor were directly exposed to the sun, such an exposure would produce a spurious output. Varying illumination and reflectivity on the surface of the earth would also generate spurious signals, because the reflected radiation is principally in the wavebands to which the sensor is responded; however, these signals were cancelled at the ground stations by a time-discrimination process utilizing specially designed inhibit circuits.

The electrical output of the sensor was a trapezoidal pulse. In order to avoid stability problems with either low-frequency or d-c amplifiers, and to eliminate drift caused by changing ambient temperature, the sensor output was differentiated and amplified by intermediate electronics before being transmitted from the satellite.

At the ground station, the attitude data was fed to the attitude-pulse selector. The attitude-pulse selector separated the valid leading and trailing edges of the earth-scan pulse from spurious amplitude changes caused when cloud transitions were scanned. Subsequently, the leading edge of a valid pulse was developed into a pulse representing a sky-earth transition and the trailing edge of a valid pulse was developed into a pulse representing an earth-sky transition. These two pulses were then applied to a digital time-measuring device to measure the interval between a sky-earth transition and the following earth-sky transition. The measured time interval was recorded by punching a paper tape in a standard teletype format. The data thus recorded was later processed to determine the attitude of the satellite's spin axis corresponding to the earth-scan interval.

2. North-Indicator Subsystem

The north-indicator subsystem provided electrical data for the determination of the satellite's orientation angle (i.e., the angle in the plane of the satellite baseplate between a zero-reference radial of the satellite and the bearing of the sun) at the beginning of each picture and, thereby, the orientation of the transmitted TV picture. This data was transmitted to the ground stations on a separate subcarrier of the transmitted TV carrier. The satellite orientation was used in conjunction with data from the ephemerides to determine the north direction of the pictures transmitted from the satellite.

Nine sun-angle sensor units formed the first link in the data chain that provided the north-indicator data. Each sensor unit consisted of a solar cell mounted behind a slit-type aperture in a special housing with its sensitive surface perpendicular to a satellite radial. The units were mounted at 4-degree intervals around the vertical walls of the satellite housing.

As the satellite rotated, the slits swept across the direct rays of the sun, causing the sensor cells to generate sun-triggered pulses. These pulses triggered coded multivibrators located in the sun-sensor electronics package. Because of the sensor spacing and because of the 8- to 12-rpm spin rate, a minimum of two of these coded pulses occurred during each 2-second picture read-out. The coding of the multivibrator output pulses was sequenced in such a way that any two consecutive pulses uniquely defined a sun-sensor location. These pulses were amplified, shaped in the sun-sensor electronics package, and applied to the tape-recorder electronics.

In the tape-recorder electronics, the pulses were used to key a 10-kc subcarrier oscillator to provide 10-kc tone bursts with durations equal to those of the input pulses. If pictures were being taken in the remote mode (i.e., while the satellite was beyond the range of a ground station), the tone bursts were recorded by the tape recorder, along with the corresponding video information, and were stored until the satellite was commanded to play back. The tone bursts (along with the video information) were then "read back" into the electronics where the tone bursts were again used to key the 10-kc subcarrier oscillator. The output of the oscillator was modulated on the TV carrier for transmission to the ground. When a sequence of direct pictures was being taken, the tone bursts by-passed the tape recorder and were combined with the camera video subcarrier for direct transmission to the ground with the video.

At the CDA ground station the sun-angle information was separated from the video signal by a bandpass filter. The tone bursts were then detected and applied to the sun-angle computer. The computer identified the particular baseplate-referenced sun sensor associated with the coded sun pulses. It then related the

occurrence times of these pulses to the initiation of the video subcarrier, and computed the sun angle. The computed-sun-angle data was displayed visually in binary form on the panel framing the kinescope and photographed along with the video display. The north direction was then determined from the sun angle data appearing on the photograph and ephemeris data corresponding to the time the TV picture was taken. The basic requirements and the initial development and design of the sun-sensor electronics are described in the TIROS I final report.

3. APT Rotation Counter

Because the APT ground stations were relatively simple installations (consisting only of an antenna, a receiver, and a facsimile recorder), the determination of picture orientation and picture center location could not be carried out by these stations in the manner available at CDA stations. Instead, certain parameters had to be calculated in advance from data compiled by the Minitrack and CDA stations and provided to the APT stations. Once the orbital parameters and spin axis path of the satellite were established, the locations of the satellite subpoint and of the picture centers were predicted for future orbits and incorporated into an ephemeris supplied to the individual APT ground stations. In addition to providing the picture center locations, it was necessary to provide the APT stations with picture orientation data (geographic directions in the pictures). This was made possible by the satellite's APT rotation counter. Since the satellite was spin-stabilized at a spin rate of 8 to 12 rpm and since the APT camera was directed along a line parallel to the spin axis, a true north direction in the picture could be determined if the orientation of the camera field-of-view was known at the time of shutter actuation. Therefore, a fixed relation was established between the start of an APT picture cycle and the sun's direction from the satellite by triggering the picture cycle using the output of one of the nine sun sensors in the satellite's north indicator subsystem. The sun sensor selected for this purpose was known as the APT rotation counter. It was located at the satellite's 220-degree baseplate radial.

The start of each APT picture-taking cycle was inhibited by internal circuitry until a pulse was received from the 220-degree sun sensor. Since the time between the start of a PED* cycle and the actuation of the camera shutter could be determined quite accurately from a measurement of the spin rate, this time delay could be translated into degrees of rotation of the satellite and the orientation at the time of shutter operation could then be accurately determined. The angle between the picture center line and the sun azimuth could, therefore, be

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* PED cylce: Prepare, expose, develop cycle. See Section V of this report.

calculated for each TV picture; and based on projections of sun location and satellite attitude, accurate determination of the north direction could be made for APT pictures taken at any point covered in the ephemeris.

C. PERFORMANCE EVALUATION

Both the north-indicator subsystem and the attitude-indicator subsystem performed satisfactorily throughout the evaluation period. The pulse widths of the coded north-indicator data were within allowable limits and spacing of the pulses was accurate. The malfunction of the number 2 telemetry commutator on orbit 331 (January 13, 1964) prevented the further reception of attitude data from the low frequency beacon. However the redundant attitude data transmitted by the high frequency beacon was available through the evaluation period and thus there was no actual loss of attitude data. Typical TIROS VIII attitude indicator data after January 13, 1964 is shown in Figure VIII-1. Since this recording was made after the malfunction of the No. 2 telemetry commutator, only one channel of attitude data appears.

The APT rotation counter worked satisfactorily throughout the period during which camera subsystem No. 2 was routinely interrogated. The picture orientation data was within allowable limits.

Figure VIII-1. Typical TIROS VIII Attitude Indicator Data after Orbit 331 (Channel 2 Telemetry Commutator was Inoperative after Orbit 331)

IX. SATELLITE DYNAMICS CONTROL

A. GENERAL

The four devices used on the TIROS VIII satellite to provide dynamics control were essentially the same as had been used on the previous TIROS satellites. These devices were as follows:

(1) A "Yo-Yo" de-spin mechanism.

(2) Spin-up rockets.

(3) The TEAM (Turned Energy-Absorption Mass) precession damping mechanism.

(4) A magnetic attitude-control (MAC) device.

B. DE-SPIN MECHANISM

1. Function

The de-spin mechanism was designed to effect rapid reduction from the spin rate imparted by the third-stage rocket, nominally 126 rpm, to the operational spin rate, nominally 8 to 12 rpm. The operational range lies between a minimum required for satellite stability and a maximum above which the satellite's spin causes smear and affects TV resolution.

A "Yo-Yo" mechanism of essentially the same design as had been used successfully on TIROS I through VII was used on TIROS VIII to achieve the spin reduction. This mechanism consisted of a pair of weights, each attached to one end of a light steet cable. The other ends of the cables were attached to diametrically opposite points on the satellite's circumference by means of simple hook-and-eye release devices. From these points, the cables were wrapped once around the periphery of the satellite just above the baseplate; the weights were attached to the satellite by explosive release mechanisms. Operation of the release mechanisms was initiated automatically shortly after separation of the satellite from the rocket. After operation of the release mechanisms, the weights moved tangentially away from the satellite, restrained by tension in the cables. As the weights moved outward, the cables unwrapped until, when extended to their full

lengths, they were released from the satellite by disengaging from the hook-and-eye devices. The temporary increase in the satellite's moment of inertia, while the cables were still attached to the satellite but the weights were at increasingly greater distances from its spin axis, caused the reduction in spin rate. (To conserve angular momentum, the satellite's angular velocity decreased as its moment of inertia increased.) Release of the weights and cables after the de-spin had been accomplished restored the moment of inertia to approximately the initial value, with a very small loss in total momentum. During the calibration phase of the test program, the spacecraft's moment of inertia was measured and the de-spin weights and cable lengths necessary to achieve the desired final spin rate were calculated. These calculations were based on an initial spin rate of 126 rpm and the weights and cable lengths were designed to provide a de-spin ratio (initial-to-final spin rate) of 0.083, to yield a final spin between the lower operational limit of 8 rpm and the upper limit of 12 rpm.

2. Performance Evaluation

The actual spin rate of the third-stage rocket and spacecraft combination was 128 rpm, 2 rpm above the nominal value. The de-spin mechanism activated normally, approximately 5 minutes after separation of the satellite from the third-stage rocket. After spin down, the satellite spin rate was 10.1 rpm, approximately in the center of the operating range of 8 to 12 rpm. The de-spin ratio was thus 10.1/128, or 0.078, somewhat lower than the theoretical value of 0.083 which is based on the measured satellite moments of inertia, an initial spin rate of 126 rpm, the measured cable lengths, and the weights of the de-spin masses.

C. SPIN-UP ROCKETS

1. Function

The satellite's spin rate is gradually reduced in orbit because eddy currents induced in current-conducting parts of the satellite as the result of its passage through the earth's magnetic field produce fields which oppose the inducing field. In order to maintain a spin rate above 8 rpm, (the minimum spin required for stability), the satellite is equipped with spin-up rockets which can be fired in pairs by ground command when the spin rate has decayed to the minimum value. As on the previous TIROS satellites, TIROS VIII was equipped with five pairs of spin-up rockets, the two rockets in each pair being located diametrically opposite each other. The rockets were designed to produce an increase in the spin rate of approximately 3.5 rpm as the result of the firing of each pair. The theoretical spin-up differs for each satellite because of different moments of inertia.

2. Performance Evaluation

The spin-up history of TIROS VIII is given in Table IX-1. All spin-ups produced spin rate increases very close to the nominal value of 3.5 rpm for which the rockets are designed.

TABLE IX-1. TIROS VIII SPIN-UP DATA

Date (Orbit)	Spin Rate Before Spin-Up (rpm)	Spin Rate After Spin-Up (rpm)	Increase In Spin Rate (Δrpm)
May 1, 1964 (1918)	8.362	11.937	3.575
February 8, 1965 (6017)	8.26	11.78	3.52
November 12, 1965 (10,026)	8.16	11.53	3.37

D. PRECESSION DAMPING DEVICE

1. Function

The precession damping device is designed to reduce the nutation or "wobble" of the satellite's spin axis to a small value soon after separation of the satellite from the third-stage rocket and after any other perturbation of the spin axis such as might be caused by the firing of spin-up rockets. The device is a tuned energy absorption mechanism which converts the energy of nutation into heat. Nutation of the satellite forces the movement of small weights back and forth along slightly curved monorails mounted inside the satellite hat with their chords parallel to the satellite's spin axis. The friction between the weights and the rails dissipates nutational energy in heat as the weights travel first in one direction and then in the other until the nutation angle is reduced to a very small value.

2. Performance Evaluation

A study was made of the nutation of the TIROS VIII satellite using data taken during orbits 1, 2, 6, 7, 21, 234, 445, 601, 761, 1004, 1223, 1410, and 1610.

Figure IX-1 shows the nutation cone half-angles, as calculated by means of the equation:

$$\Theta = \frac{\Delta T_{max}\ \omega_{sp} \tan \gamma}{2 \sin \pi \psi_K}, \quad *$$

where

ΔT_{max} is the maximum deviation in spin period,

ω_{sp} is the angular velocity of the satellite,

γ is the sun angle, i.e., the angle between the spin axis and the sun vector, and

ψ_K is $\left(1 - \frac{\text{I spin}}{\text{I transverse}}\right)$,

and the limiting ("breakaway") nutation half-angle, calculated from:

$$\Theta_{min} = \frac{f}{B\ r\ m\ \dot{\psi}^2},$$

where

f is the friction force acting on the damper moving cart (pounds),

B is the amplification factor,

r is the distance of the rod from the center of mass of the vehicle (inches),

m is the mass of the TEAM damper cart ($\frac{\text{lb - sec}^2}{\text{inch}}$), and

ψ is the forcing frequency ($\frac{\text{radians}}{\text{second}}$).

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*The derivation of this equation and the "breakaway" angle equation are given in Final Comprehensive Technical Report TIROS I Meteorological Satellite System, Volume III, Appendix D, and in The TIROS II Meteorological Satellite System Post-Launch Evaluation Report, Appendix B, respectively.

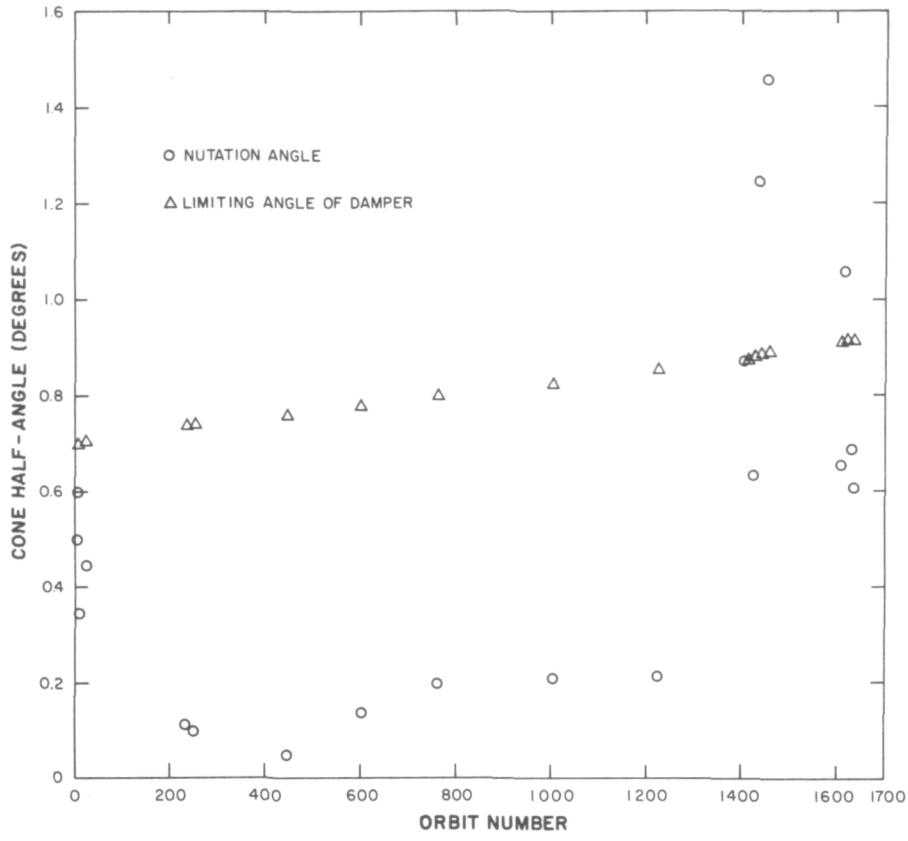

Figure IX-1. Nutation and Limiting Cone Half-Angles vs Orbit Number

Both angles are plotted against orbit number. All of the first day's orbits for which there was data (orbits 1, 2, 6 and 7) and the next orbit for which there was data (orbit 21) were studied. Following orbit 21, orbits at approximately 200-orbit intervals were chosen, using orbits 234, 445, 601, 761, 1004, 1223, 1410 and 1610. Orbit 250, which was also investigated, provided good spin data before and after playback operation and showed no effect of tape recorder operation on nutation. Due to high nutation half-angles on orbits 1410 and 1610, several other orbits following each of these orbits were investigated. These were orbits 1424, 1439, 1453, 1618, 1632, and 1633.

The first orbit shows a cone half-angle of 0.70 degree which is the same as the theoretical limiting value. The half-angle drops rapidly to 0.34 degree and then more slowly to between 0.1 and 0.2 degree where it remains steady for over 1000 orbits. Since the energy losses of the system itself should result in decreasing half-angles during this time, it appears that some form of energy was disturbing the system. By orbit 1410, the cone half-angle rose to 0.87 degree (the breakaway angle) and, after dropping to 0.63 degree, rose to 1.45 degree showing no

signs of precession damping in the data examined. It can be shown, using the equation,

$$t = \frac{2\pi}{\dot{\psi}} \cdot \frac{\Delta T}{4 f X_3} ,$$

that the time taken by the TEAM mechanism to reduce nutation from a half-angle of 1.45 degree to a half-angle of 0.89 degree (the breakaway angle) would be 54.86 seconds or 8 complete spins of the satellite. It is apparent that this should have been noticeable in the data plotted in Figure IX-2 if damping had occurred. Since there is no evidence of damping throughout the length of the plot, it has been concluded that the traveling mass froze to the rod. By orbit 1610, the half-angle was again reduced to a value below that of the breakaway angle but again this could have resulted from other energy losses than those of the TEAM damper.

It appears that, during the first orbit, the TEAM damper quickly reduced any nutation to its limiting value, then other damping (possibly, but not probably, including the TEAM damper) and outside perturbing torques were balanced. The satellite remained in this condition until some time after orbit 1200 when more violent perturbing torques were apparently experienced. It appears that the

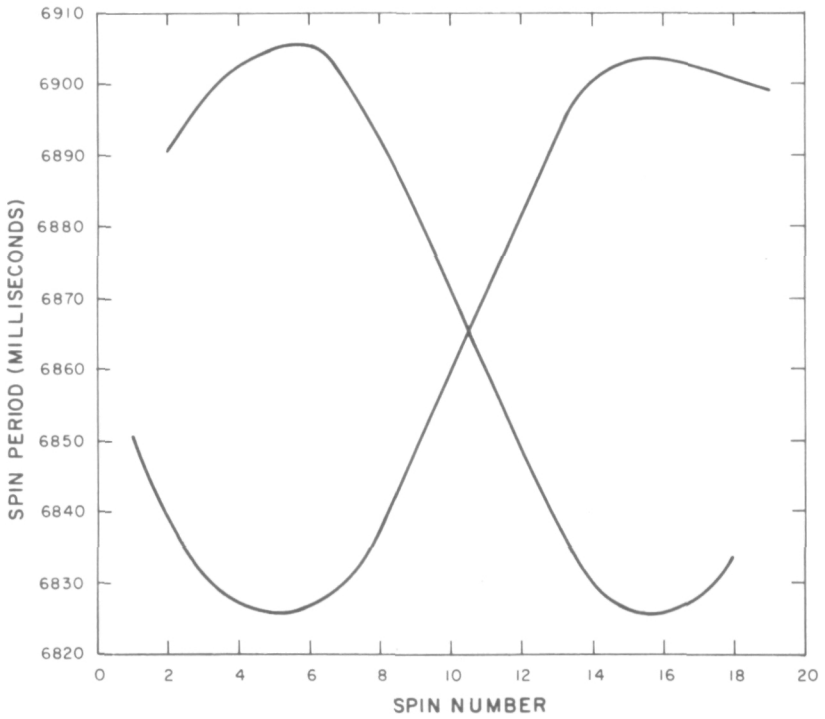

Figure IX-2. Spin Period vs Spin Number, Orbit 1453

TEAM damper did not operate to damp out the induced nutation unless the perturbing torques were continuously applied during and before the spin observations.

On May 1, 1965 TIROS VIII was spun-up on orbit 1918 from 8.362 to 11.937 rpm. A study of spin period (north indicator or S-9) data was done for orbits 1918, 1919, 1920 and 1932 in order to determine what effect the spin-up had on the nutation of the spin axis.

Prior to spin-up, the nutation half-angle was 0.450 degree while the "break-away" angle was calculated to be 0.943 degree. After spin-up occurred, the nutation angle appeared to be 0.561 degree which is essentially the same as the "break-away" angle of 0.545 degree. On the following orbit the nutation angle was apparently 0.559 degree.

Apparently, during this spin-up, there was only a small perturbation of the spin-axis and the nutation cone angle did not rise above the "break-away" angle of the TEAM damper mechanism. Thus the slight decrease in the nutation angle was probably due to energy losses other than those of the TEAM dampers.

E. ATTITUDE PREDICTION, MEASUREMENT, AND CONTROL

1. Function

The TIROS VIII satellite was provided with a magnetic attitude control (MAC) switch and coil as the means for attitude control by ground command. Attitude measurements and predictions were prepared to evaluate the need for attitude changes. As on the past TIROS satellites, the attitude predictions were used in computing power availability and picture programming. Any desired changes in attitude were made by commanding the necessary change in the MAC switch setting. Such changes included those necessary to cancel the effect of the satellite's own residual dipole moment.

2. Performance Evaluation

The TIROS VIII attitude program began with the measurements of the dipole moments of the spacecraft (including calibration of the MAC switch) and the computation of initial 90-day pre-launch predictions of satellite attitude. In the course of the dipole moment measurements, permanent trimmer magnets were added to the spacecraft to reduce the residual dipole moments to very small values. These values were recorded and used, together with the planned time of launch, to compute the initial predictions. A program of MAC switch operation was also prepared to yield an optimum spin-axis path during the early orbits.

No changes in settings of the MAC switch were programmed for the first several hundred orbits, so that the only dipole moment acting on the satellite during this period was the residual dipole moment. The accuracy of the measured dipole moments was evaluated by comparing the predictions with the observed attitude. Trial computations were made until the exact values of the dipole moments that would account for the observed motion were determined. (The accuracy of these re-evaluations is apparent from the fact that the predictions based on the new values typically remained valid over several thousands of orbits.) After the satellite had been placed in orbit, its attitude in terms of the celestial coordinates of the normal point of the spin axis, was measured for each orbit. When a change in satellite attitude was desired, to gain a more favorable sun angle or camera nadir angle, a change in the MAC switch setting was commanded. The MAC switch was also used to compensate for any undesired attitude drift that became apparent in a comparison of predicted and measured attitude.

This program of attitude prediction, measurement and control was used with good effectiveness during TIROS VIII operation in orbit. The predicted and observed attitude plots in right ascension and declination of the spin axis normal point are given in Figures IX-3 and IX-4.

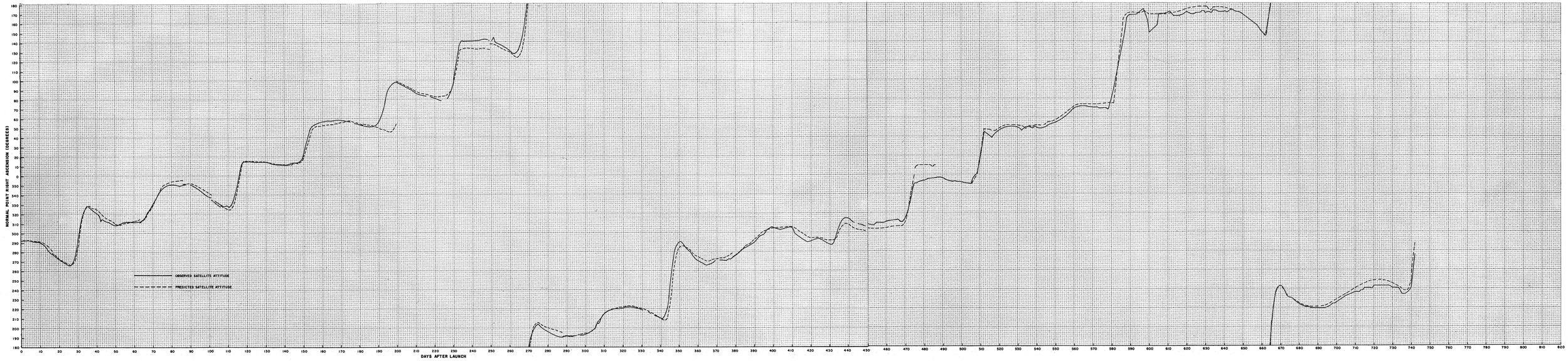

Figure IX-3. Spin-Axis Normal Point Right Ascension vs Days After Launch

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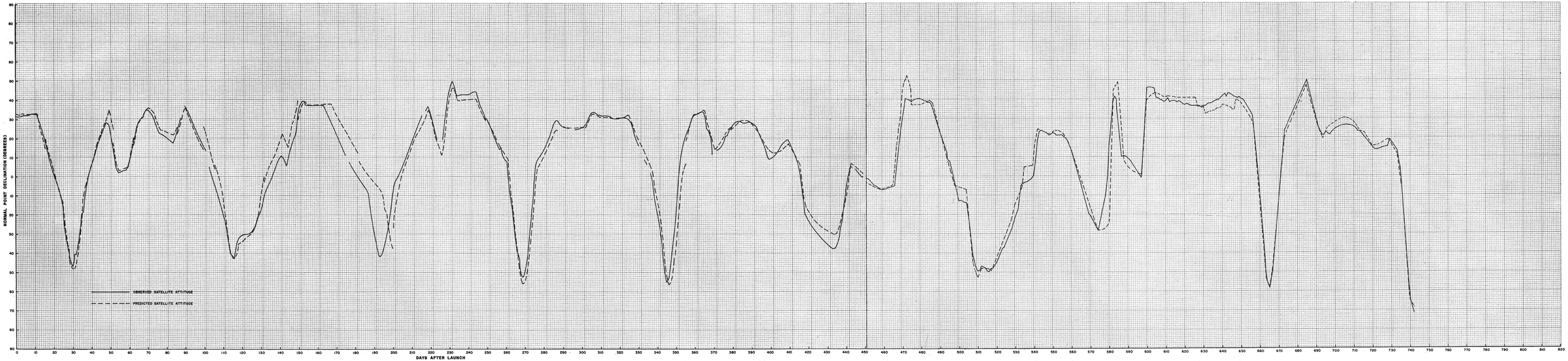

Figure IX-4. Spin-Axis Normal Point Declination vs Days After Launch

X. ANTENNAS

A. FUNCTION

1. General

The satellite antennas provided the means for the reception of command signals from the CDA ground stations and for the simultaneous radiation of energy from three separate transmitters (both beacons and TV transmitter No. 1), or from two separate transmitters (beacon No. 2 and TV transmitter No. 2). A network was provided for coupling and matching the receivers and transmitters to the antennas and for isolating the active transmitters and the two command receivers.

The CDA ground station antennas provided for the reception of the TV and beacon signals from the satellite and for the transmission of command signals to the satellite.

The antennas were basically the same as those used for TIROS VII. A hybrid diplexer was added to the standard TIROS matching and coupling network (used on TIROS VII) to accommodate the 136-Mc APT transmitter and an antenna filter was added to the command antenna to prevent APT transmissions from blocking the command receivers.

2. Satellite Antennas

The satellite command receivers utilized a dipole receiving antenna consisting of a single vertical "whip". The beacon and TV transmitters shared two cross-dipole antennas (two frequencies) by means of a coupling and matching network and a hybrid diplexer which coupled the four antenna segments to achieve a circularly polarized output.

The antennas and the coupling and matching network used on TIROS VIII were similar in design and construction to those used on previous TIROS satellites. The addition of the relatively highpower (5-watt) APT transmitter which operated on a frequency (136.95 Mc) close to those used by both beacons required the following modifications to minimize mutual interference.

(1) Retuning the 136 Mc portion of the crossed dipole antennas to the APT transmitter frequency, 136.95 Mc. (In previous TIROS satellites, the antennas were tuned to 136.57 Mc, the mean frequency between the 136.23- and 136.92-Mc beacon frequencies).

(2) The 235-Mc sections of the crossed-dipole antenna were tuned to match the 235-Mc output of the single TIROS camera subsystem instead of to 236.4 Mc, the mean frequency between the TV and IR equipment on previous TIROS satellites.

(3) A hybrid diplexer was added to the coupling and matching network. The diplexer was used to combine the two beacon output signals. One output from the diplexer was connected to the 136-Mc input on the standard TIROS coupler. The remaining diplexer output was terminated by a 50-ohm resistive load. The APT transmitter output was connected to the remaining 136-Mc input to the standard TIROS coupler. The other 236-Mc input to the standard coupler was terminated by a 50-ohm resistive load.

(4) An antenna filter was added to the command antenna to prevent the 5-watt APT transmitter from blocking the command receivers at maximum slant-range distances.

The matching and coupling network and the hybrid diplexer for the transmitting antennas provided:

(1) coupling of at least two transmitters in each frequency band to the radiating elements with a minimum of feedback between transmitters,

(2) sufficient isolation to prevent interaction between transmitters operating in different frequency bands, and

(3) division of energy from each transmitter into four branches so that the currents were of equal magnitude in all branches and were properly phased to produced circular polarization.

3. Ground Station Antennas

Signals from the standard TIROS camera subsystem on the TIROS VIII satellite were received by a 60-foot parabolic antenna at the PMR ground station. The Wallops Island ground station was equipped with three antennas. A General Bronze swept-volume efficiency antenna, having a gain of 39 db and similar in design to the antenna at the AED station, was used to receive the TV signals in the 235-Mc region, a crossed-helix antenna was used for receiving the 136-Mc Beacon signals, and an aluminum helix was used for receiving the 136-Mc APT signals. The command antenna at Wallops Island was located on the same mount as the 136-Mc antenna. At the PMR station the command antenna was mounted on the upper rim of the 60-foot antenna. The Alaska

station, which began operations in September, 1963, made use of a Blaw-Knox 85-foot parabolic dish antenna on an X-Y mount. Dipole elements for 136-Mc and 235-Mc were located at the focal point of the dish. The antennas at all three stations were capable of manual or automatic tracking of the satellite. At all CDA stations, the APT (camera subsystem No. 2) signals were received by an aluminum helix antenna.

B. PERFORMANCE EVALUATION

Performance of the satellite antennas in all frequency ranges was normal in every respect throughout the evaluation period covered in this report. Satisfactory signal strengths from the satellite transmitters were reported by the CDA stations and by the AED back-up station, indicating that performance of the transmitting antennas and the antenna matching and coupling network was normal. The consistently good response of the satellite to ground commands gave evidence of satisfactory performance of the command receiving antenna.

XI. ELECTRICAL POWER SUPPLY SUBSYSTEM

A. FUNCTION

Electrical power for all TIROS VIII satellite subsystems was supplied by a power supply consisting of a solar-energy converter and three batteries of storage cells. Each battery consisted of 21 series-connected nickel-cadmium cells. The total battery capacity was 11.7 ampere-hours. The solar-energy converter consisted of an array of 9120 silicon solar cells, mounted on the top and sides of the satellite structure which, during orbital day, produced electrical currents for powering the subsystems and maintaining the battery charge. If the peak-power requirements of the satellite subsystems exceeded the power output of the solar cells, the batteries supplied the difference. During orbital night, the storage batteries supplied all of the power required by the satellite.

Protective circuits were included in the subsystem to prevent internal circulating currents in the power supply interconnections and to preclude the total loss of power in the event that a short circuit occurred in an individual cell or battery.

Each 21-cell battery was connected to the solar-cell supply through its own current regulator to limit the rate of battery charge to a safe value. The excess power generated by the solar array was diverted through a bypass regulator to the main battery-output bus. During orbital night, when the solar cells were passive, silicon diodes in each series row of solar cells prevented the storage batteries from discharging into the solar cells. A similar function was performed by diodes included in each series row of solar cells located on the lateral surfaces of the satellite. Because of the satellite's rotation, each series row of solar cells on a lateral surface was alternately illuminated and then darkened. The diodes prevented the darkened solar-cell rows from loading the illuminated rows. The storage batteries provided a relatively constant voltage across the solar cells, thereby isolating them from variations in the electrical load.

The TIROS VIII electrical power supply subsystem was identical to that of the TIROS VII satellite. One-half of the silicon solar cells were of the "gridded" type, having an efficiency of 9.25 percent as compared with the 7.25-percent efficiency of the non-gridded cells.

B. PERFORMANCE EVALUATION

1. General

The power supply subsystem on TIROS VIII performed extremely well. The subsystem was successful in both:

(1) maintaining a balance between available energy and energy expended, and

(2) maintaining a minimum battery voltage of -26 volts.

2. Energy Balance on TIROS VIII

Energy available is dependent on the angle of incidence of the sun's rays on the satellite (the amount of solar energy converted by the cell varies with the angle of incidence of the sun's rays and with cell temperature) and on the percentage of each orbit during which the satellite is illuminated by the sun. The energy available is predicted for each day in orbit from predictions of satellite attitude and orbit path. Energy used is budgeted on a daily basis so that the programming planned for one day will not expend more energy than is converted during that same day by the solar array and so that sufficient energy is expended to prevent overcharge of the batteries. The energy available for each orbit day in the first 12 months and in the final month of the evaluation period is shown in Figure XI-1. Also shown is the daily energy expenditure. On all days of the period examined, the energy available exceeded the energy used. The total daily average power required varied between 8.1 and 20.5 watts. The power required by the satellite with no programming was 7.9 watts. In general, the curves indicate good practices in the utilization of available energy on TIROS VIII as well as normal performance of the solar array, batteries and power supply circuits.

3. Battery (Unregulated Bus) Voltage on TIROS VIII

The daily battery-row voltage telemetered during the first twelve months of the evaluation period and during the final month of the period is shown in Figure XI-2. This voltage is from 0.5 to 1.0 volt higher than the unregulated bus voltage because of small voltage drops in the germanium diodes that are used to isolate the battery rows from each other.

The nominal unregulated bus voltage at which the power supply regulators cease to provide regulation is -26 volts. If the unregulated bus voltage should decrease and remain below -26 volts on two successive telemetry readouts, standard procedures call for immediate suspension of programming until the telemetered unregulated bus voltage returns to normal. On TIROS VIII, the bus voltage was above -26 volts on all days of the period examined.

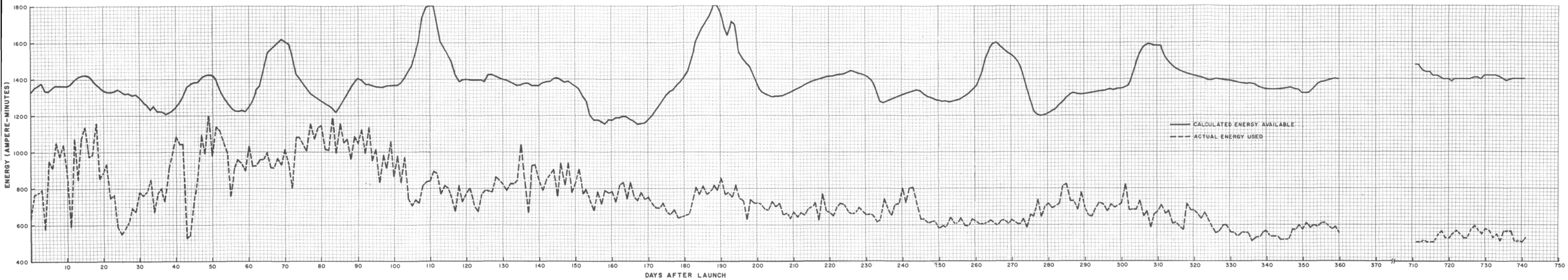

Figure XI-1. Energy Available and Energy Expended vs Days After Launch

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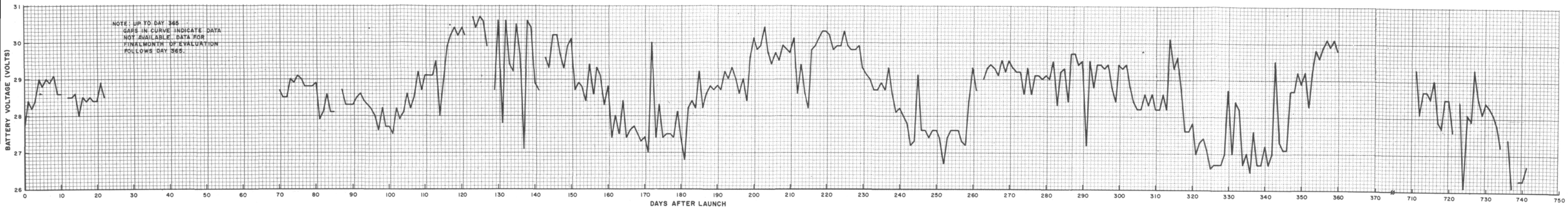

Figure XI-2. Unregulated Power Supply Bus Voltage vs Days After Launch

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4. Solar Patch Telemetry

A group of 60 series-connected solar cells, located on top of the TIROS VIII "hat," was isolated from the remainder of the cells in the solar array and provided with a fixed load resistance. The load resistance consisted of two resistors connected in series to form a voltage divider that provided a telemetry voltage (nominally 2.50 volts under optimum conditions for solar conversion). This solar-cell patch was calibrated during the test and calibration phase of the TIROS VIII engineering program so that, during orbital operation of the satellite, the output could be predicted as a function of sun angle (γ), solar cell temperature and percent sun-time; the telemetered value (V_T) could then be compared with the computed value (V_C) to obtain an indication of any changes in solar cell performance. Any changes due to charged particle or micrometeorite bombardment of the cells could be expected to affect the entire solar array, including the telemetered patch, and would be apparent as a deviation of the telemetered from the predicted solar patch voltage.

A ratio of the values, V_T/V_C, was used to provide a convenient indication of any change in the condition of the solar cells. A plot of this ratio for the first year of operation is shown in Figure XI-3. Because the calibration curves employed to determine V_C are based on absolute measurement, V_T should be equal to V_C on the day of launch and on day 001. However, on the day of launch V_T/V_C was 1.20 and on days 001 and 002, V_T/V_C was 1.10. No apparent trend could be determined from the ratio of telemetered voltage to calculated voltage. The data appeared to be erratic and the ratio was zero during the month of December 1965, the final month covered in this evaluation. A combination of one or more factors could account for the sporadic readings in the ratio derivations.

(1) The calibration curves derived prior to launch were in error,

(2) An intermittent high resistance developed in series with the solar cells which provide the telemetry signal,

(3) An intermittent partial short circuit developed in the solar cell telemetry patch.

Of these possibilities, one of the latter two is the most probable since the telemetry voltage eventually decreased to zero.

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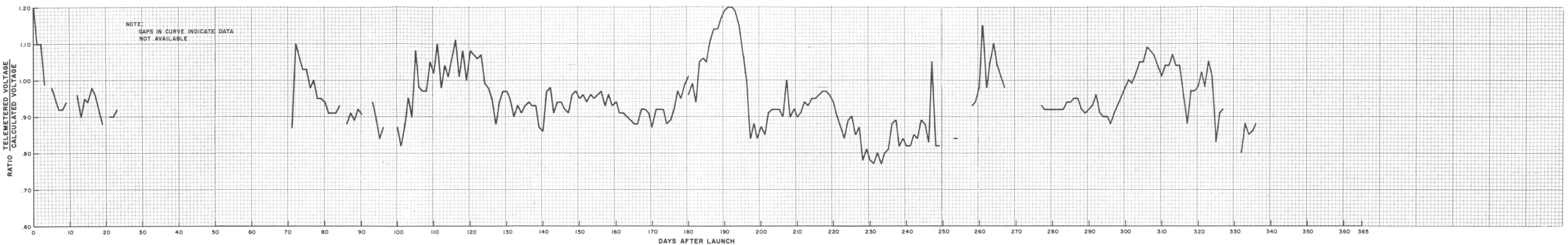

Figure XI-3. Solar-Cell Patch Voltage Ratio (V_T/V_C) vs Days After Launch

XII. SATELLITE THERMAL RESPONSE

A. FUNCTION

The thermal design of TIROS VIII was essentially the same as that of TIROS VII, employing the same passive temperature-control techniques to maintain the temperature of the satellite components within allowable design temperature extremes and to help maintain the temperature of the solar cells within the limits required for good conversion efficiency.

The physical properties and operating parameters of the APT components were similar to those of the standard TIROS components. Detailed thermal analysis indicated that, under certain conditions, the APT camera temperature could drop below -10°C. The finish on the camera lens housing was therefore changed to aluminized mylar to reduce its emissivity from 0.5 to 0.1 and to bring the minimum APT camera temperature within an acceptable range. The thermal analysis indicated that the camera, with a maximum continuous operating period of 30 minutes, would not reach a temperature significantly above the average component temperature.

Detailed thermal analysis of the APT transmitter indicated that, with little or no conduction into the baseplate, the maximum transmitter temperature would be 63°C; with some conduction into the baseplate, the maximum temperature would be 43°C. The transmitter was rated for 70°C and would have operated well within this limit. However, thermal-vacuum testing required the transmitter to operate after having been exposed to a 50°C ambient temperature for 72 hours. For the assumptions of (a) little or no conduction into the baseplate and (b) some conduction into the baseplate, the maximum transmitter operating temperatures would be 88°C and 68°C, respectively. The maximum temperature was lowered to within acceptable limits by the addition of a 2.5-pound* heat sink directly beneath the transmitter. Quilted silver foil was used as an interface between the heat sink and the transmitter.

To permit accurate monitoring of the actual operating temperatures in the orbiting satellite, 14 temperature sensors were mounted at various locations on the satellite. The locations of the sensors and their operating ranges are given in Table XII-1.

*The maximum weight which could be added at that location without disturbing the dynamic balance of the spacecraft.

TABLE XII-1. LOCATION OF TEMPERATURE SENSORS ON TIROS VIII

Sensor No.	Location	Operating Range (°C)
1	Baseplate, at 300-degree location	-20 to +10
2	Baseplate, at 300-degree location	-10 to +40
3	Baseplate, at 300-degree location	-30 to +100
4	Battery Pack	-10 to +40
5	APT Clock (Clock No. 2)	-10 to +40
6	TIROS Transmitter	-10 to +40
7	Horizon Scanner	-10 to +40
8	APT Camera	-10 to +40
9	Inner Top-skin, at 3-inch radius	-30 to +100
10	Inner Top-skin, at 12-inch radius	-30 to +100
11	Solar Cells, at 3-inch radius	-30 to +100
12	Side Panel, at 30-degree location	-30 to +100
13	APT Transmitter	-30 to +100
14	1.5-Year Timer, at 60-degree location	-20 to +10

B. PERFORMANCE EVALUATION

All components of the TIROS VIII satellite remained within the predicted temperature ranges with the exception of the APT vidicon target. The APT vidicon target temperature, as shown in Figure XII-1, decreased from an initial value of +7°C to -7°C on Julian day 20 (orbit 331), the day on which the telemetry switch carrying vidicon target temperature telemetry failed. After that date, the vidicon target temperature could no longer be monitored. However, from the telemetered values of other satellite temperatures, it is known that the satellite experienced its minimum temperatures on Julian day 55. The vidicon target temperature was estimated for day 55 from other satellite temperatures that were available (clock No. 2 and battery). A relationship between these temperatures and vidicon target temperature similar to that existing before orbit 331 was assumed. The value arrived at by this method was -16°C, suggesting a possible change in emissivity of the aluminized mylar coating used on the camera housing to prevent low camera temperatures. However, no positive determination of a change in characteristics of the mylar coating could be made. Using data from the last available telemetry for vidicon target temperature, it was established that on Julian day 20 (when the vidicon target temperature was -7°C), the effective emissivity was 0.18, a value that indicated the aluminized finish had retained its original integrity up to that time. The plot of emissivity versus temperature used to obtain this value is shown in Figure XII-2.

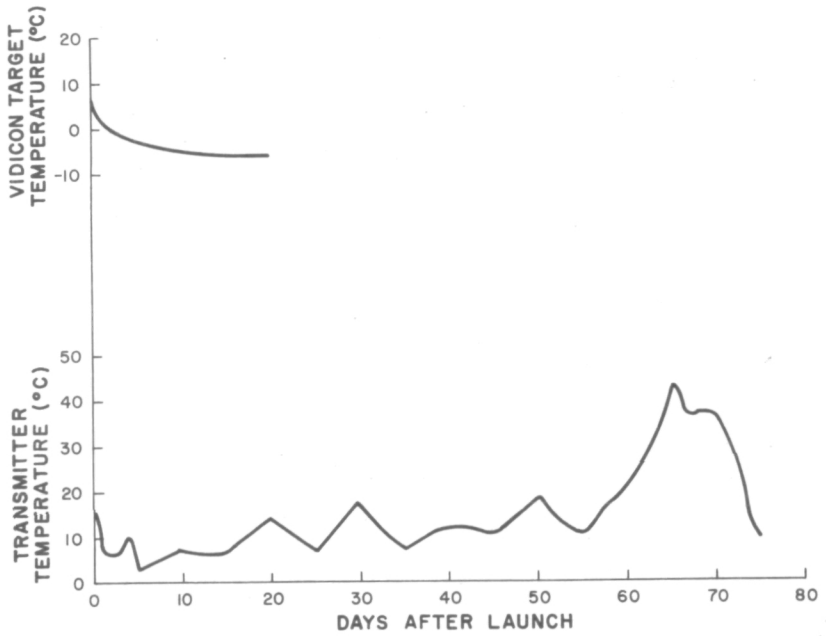

Figure XII-1. APT Vidicon Target Temperature and APT Transmitter Temperature vs Days After Launch

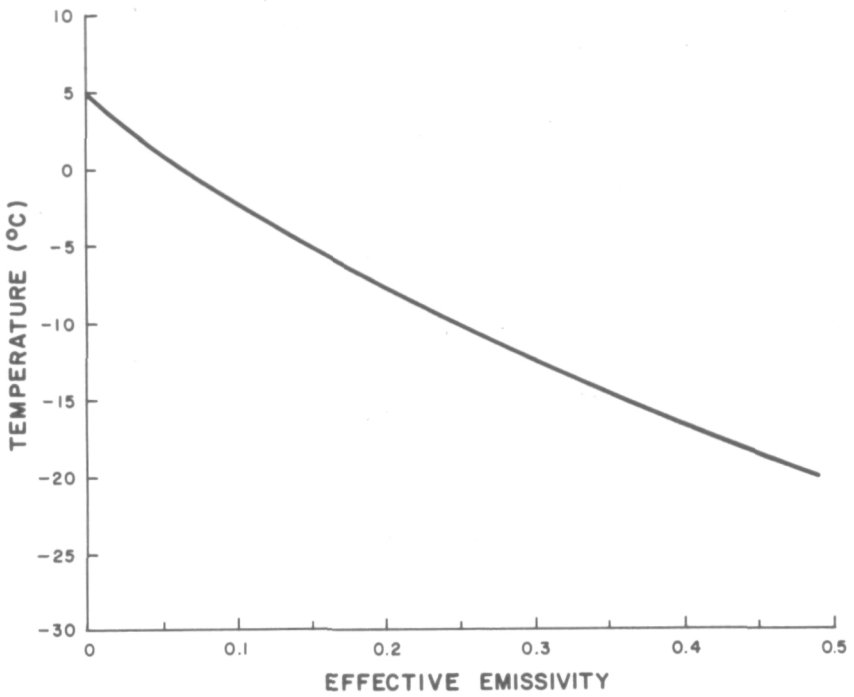

Figure XII-2. Effective Emissivity vs Temperature for APT Camera on TIROS VIII with Aluminized Mylar Coating

The APT transmitter temperature is also shown in Figure XII-1. The maximum APT transmitter temperature, during 100 percent suntime, was 43°C compared with its rated maximum of 70°C. This was a maximum rise of 11°C above the standard TIROS components. The heat sink that was added to this component so that it would survive thermal vacuum tests was not of significance in the space environment, which is less severe than that of the tests.

Figures XII-3 through XII-7 are plots of daily minimum and maximum structure temperatures (top, side, and baseplate), battery temperature, and component (clock No. 2) temperature taken from daily telemetry recordings. Data is plotted for the first year of evaluation and for the final month (December 1965) of the evaluation period. Plots of the satellite sun (gamma) angle and the percent sun-time are shown in Figure XII-8.

The temperatures of all standard TIROS components remained within the specified range of 0°C to 35°C in the data examined. Normal temperatures were still being experienced at the conclusion of the evaluation period as shown in the data for December 1965. The APT transmitter operated within the range of 3°C to 43°C, well inside its temperature limits. The APT vidicon target operated in the range between -16°C and +5°C. This was lower than the predicted range of -1°C to +25°C. (The minimum temperature, -16°C, on the vidicon target is an extrapolated figure and not a telemetry readout.)

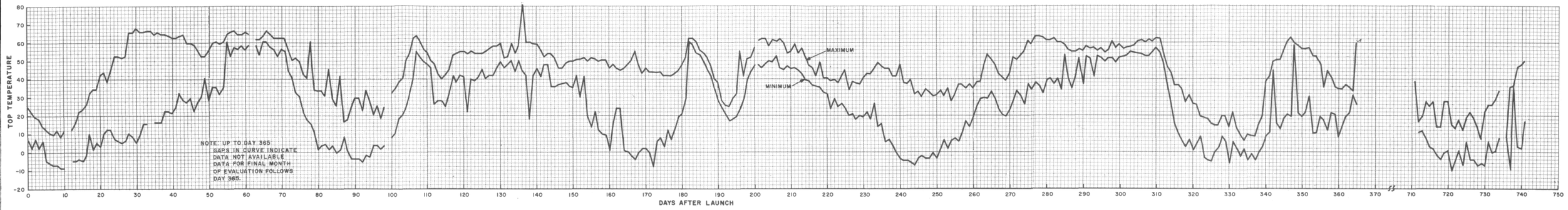

Figure XII-3. Satellite Top Temperature vs Days After Launch

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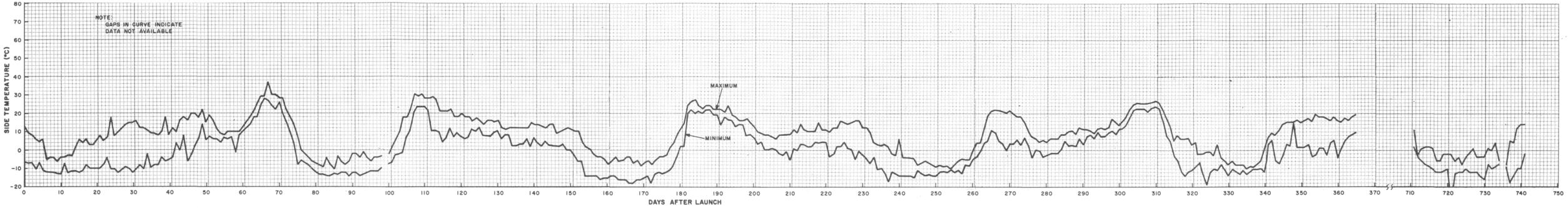

Figure XII-4. Satellite Side Temperature vs Days After Launch

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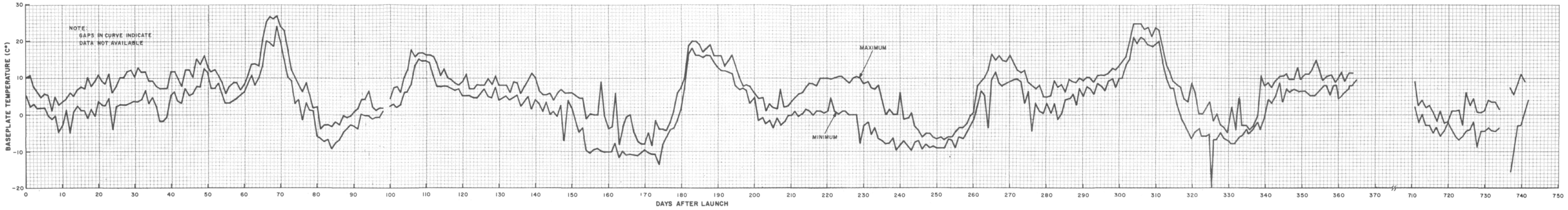

Figure XII-5. Satellite Baseplate Temperature vs Days After Launch

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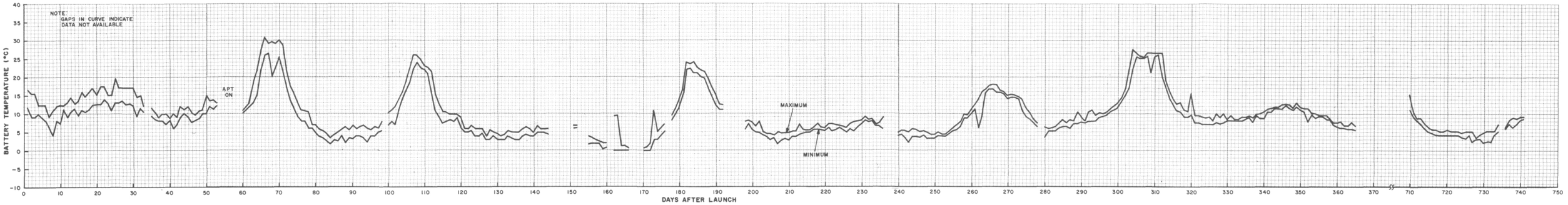

Figure XII-6. Satellite Battery Temperature vs Days After Launch

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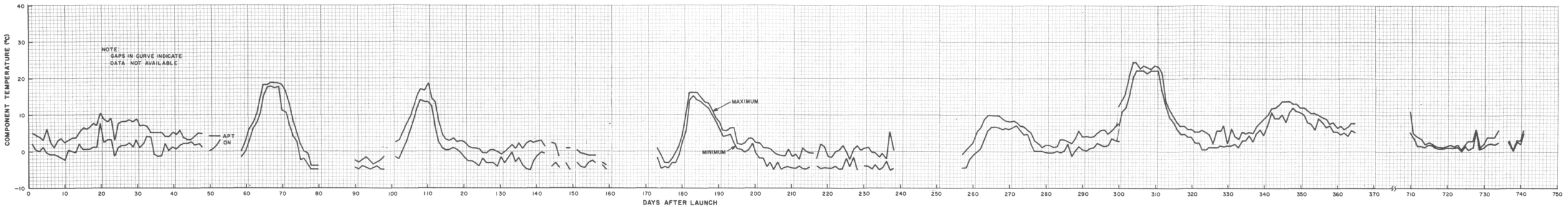

Figure XII-7. Satellite Component (Clock No. 2) Temperature vs Days After Launch

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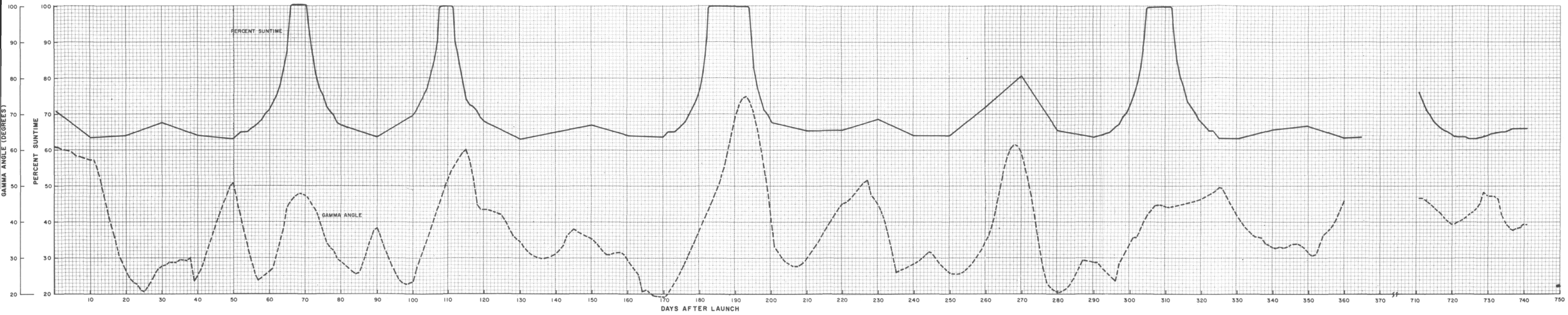

Figure XII-8. Gamma Angle and Percent Suntime vs Days After Launch

XIII. GROUND SUPPORT

A. LAUNCH SUPPORT

1. Launch Operations

In accordance with contractual launch support requirements, AED engineering personnel participated in the TIROS VIII launch operations tasks performed at Cape Kennedy, Florida. These tasks included checkouts of the spacecraft, radio-frequency interference testing, mating of the spacecraft with the launch vehicle, and checkout during the countdown. The operations took place over a period of 19 days, beginning with the arrival of the spacecraft and checkout van at Cape Kennedy on December 3, 1963. The TIROS VIII launch operations are described in detail in the TIROS VIII Final Engineering Report and are summarized in this report in Table XIII-1.

The spacecraft tasks were performed without mishap, and the spacecraft subsystems responded normally to all testing. Several postponements of the launch were occasioned by problems in the launch vehicle, but none by spacecraft problems. On December 21, at 0355 hours EST, the terminal countdown began and proceeded to lift-off at 0430:00.24 EST. The launch events occurred normally, and satellite separation occurred at approximately T + 760 seconds.

2. Orbital Data

The satellite spin rate at injection was 128 rpm. After de-spin, the rate was 10.1 rpm. The satellite entered a nearly circular orbit with an apogee of 468.37 statute miles and a perigee of 434.95 statute miles. The orbit was inclined to the equator at 58.5 degrees. The period of orbit was 99.35 minutes.

B. COMMAND AND DATA ACQUISITION STATIONS

1. Introduction

Three primary Command and Data Acquisition (CDA) ground stations were included in the TIROS VIII ground complex. These were located at the Pacific Missile Range (PMR), with installations at Point Mugu and San Nicolas Island; at Wallops Island, Virginia; and at Gilmore Creek, near Fairbanks, Alaska.

TABLE XIII-1. CHRONOLOGY OF TIROS VIII LAUNCH OPERATIONS

Date	Event
December 2	Flight-model spacecraft (F8), prototype spacecraft (T-2A), and Go, No-Go checkout van shipped from AED, Princeton, N. J.
December 3	All equipment arrived in normal condition at Cape Kennedy, Florida.
December 4	Standard electrical performance evaluation test performed on F8 with satisfactory results.
December 5	Task 4 checkout performed on F8 with satisfactory results.
December 6	Prototype spacecraft (T-2A) mated with dummy third stage rocket for site RF interference tests. Test results satisfactory. Prototype spacecraft and third stage mounted on second stage rocket on launch pad and RF interference tests and Task 4 tests performed. Test results satisfactory.
December 8	F8 solar-cell array electrical operation tested with normal results.
December 9	Task 4 test performed on F8 with satisfactory results. F8 mounted on third-stage rocket at spin-balance building. Run out of combination within tolerance.
December 10	RF interference test of F8 and third stage combination performed with satisfactory results. Task 4 test using RF link performed with satisfactory results. Spin-balance started.
December 11	Spin balance completed. Task 4 test performed with satisfactory results. F8 and third stage transported to launch pad (17B) and mounted on second stage.
December 12, 13, 14	Task 4 test, using RF link between Go, No-Go van and F8, performed with satisfactory results on each day.
December 16	F-minus-1 day operations started. Task 4 test performed with satisfactory results. Launch day postponed because of gyro problem in launch vehicle.
December 17	Task 4 test performed with satisfactory results. Launch day postponed to December 20 because of guidance equipment problem on launch vehicle.

TABLE XIII-1. CHRONOLOGY OF TIROS VIII LAUNCH OPERATIONS (Continued)

Date	Event
December 18	No spacecraft testing in accordance with rescheduled launch date.
December 19	F - minus -1 day operations started once more. Task 4 test performed with satisfactory results. F - minus -0 day started at 1650 hours. Task 4 test started at 1655 hours, completed at 1850 hours after correction of transmitter problem in Go, No-Go van. Final launch vehicle installations made.
December 20	At 0520 hours, launch postponed to December 21 because of problem in command-destruct system of launch vehicle. At 2200 hours, after correction of problem, F- minus -0 day countdown resumed.
December 21	Terminal countdown started at 0355 hours and proceeded to lift-off at 0430:00.24 EST. All launch events normal.

A secondary CDA station, located in the AED facility near Princeton, New Jersey, functioned as a back-up station for the primary Wallops Island station. All of the CDA stations, primary and secondary, consisted of four basic sections as follows:

(1) satellite command and control equipment,

(2) date-receiving components,

(3) data-processing and display components, and

(4) recording devices.

The functions of the primary CDA ground stations were as follows:

(1) to transmit radio signals to the satellite for programming its operations,

(2) to receive radio signals carrying the television, attitude, and telemetry data from the satellite,

(3) to extract data from the carrier signals,

(4) to record and identify the received data, and

(5) to relay the recorded attitude and telemetry data, along with station status reports, to the TIROS Technical Control Center, GSFC, Greenbelt, Maryland.

The back-up CDA station at the AED facility was equipped with the same functional units as the three primary stations. This station monitored the responses of the satellite to commands from the Wallops Island station and tracked the satellite during the first days following the launching of TIROS VIII.

2. Operational Evaluation

a. General

The operational performance of the CDA ground stations was generally good. In spite of the relatively heavy programming load placed on the ground stations by the simultaneous operation of two satellites, TIROS VII and TIROS VIII, ground station personnel continued to perform their functions effectively.

b. Wallops Island Station

Before the TIROS VIII launching, the Wallops Island ground station was rechecked for operational readiness. The APT ground equipment was installed by the early part of December, and installation of the APT antenna was completed on December 7. The APT ground equipment at the Wallops Island station was modified to provide means for recording and playing back APT signals using an Ampex PR-10-2 0.25-inch tape recorder.

All ground station systems at the station were checked and recalibrated during early December in preparation for the TIROS VIII launch. Checks were made on the following items of equipment: Collins transmitters, TV receivers, master clock, deflection circuits, TV monitor scope, sun-angle generators, Berkeley counter, command tone generators, tape degausser, signal generators, TV combiners, Sanborn recorders, Facsimile equipment, and beacon receivers. Sufficient time was available before the launch to check out the new drive system for the General Bronze antenna. The new system provided a substantial improvement over the previous drive system. However, difficulties were experienced with the new drive system during January, and the antenna was removed from service on four occasions.

Commands transmitted to operating TIROS spacecraft from the station were carefully monitored during the period from January 10 to January 13, for the

purpose of evaluating command effectiveness, particularly of the clock-set command. All transmissions during this period were recorded for further study.

The antenna programmers were moved from the TIROS racks and reinstalled with antenna-control equipment on the second floor of the ground station. The General Bronze antenna was removed from operation on March 11, 1964 to permit servicing of the drive system. Maintenance work was completed on March 14, and the antenna was returned to operation on that date. Additional maintenance work was performed on the elevation drive system on March 25, without removing the antenna from service.

The General Bronze antenna was removed from operation on April 9, 1964 for repair and recalibration. The required work was completed and the antenna was placed back in operation on the following day. However, because its performance was still unsatisfactory, the medium-gain antenna was used throughout the remainder of the month. The use of the medium-gain antenna resulted in a higher-than-normal noise level; however, the TV pictures received at the Wallops Island station were meteorologically useful. The General Bronze antenna was returned to service after completion of repairs and adjustments on May 4. It was again removed from service temporarily on May 15 and restored to regular service on the same day.

During the period from June 21 to 28, operations were suspended to allow the wiring changes required for the dual-TIROS Wheel system. This work was completed on June 28, and the station was immediately returned to operational status.

RF interference in the 136-Mc band was experienced throughout August 1964; however, only on August 28 was this interference severe enough to cause loss of telemetry and attitude data. RF interference at the TV frequencies was experienced on only one occasion and resulted in heavy noise on 12 of the TV pictures returned by TIROS VIII on August 21.

During August, the communications equipment was relocated from the ground-station area to the newly completed, telemetry building annex. The new location provided additional room within the ground-station area for work benches and test equipment.

During September, RF interference was particularly evident in the data received from the satellite. Some of this interference was attributable to local sources while some was of unknown origin.

High winds in the Wallops Island area on September 22 made it necessary to "stow" the General Bronze antenna. However, wind velocities were not so high as to prevent operation with the medium-gain antenna.

On October 1, a new contractor assumed responsibility for operation of the antenna systems at the Wallops Island CDA station. A number of the personnel assigned to the station were unfamiliar with station operations and difficulty was experienced in tracking the satellites. On October 8, the General Bronze antenna was removed from service because the amplitude of received signals appeared lower than normal. Investigation revealed that water had leaked into the coaxial cabling. A considerable amount of time was required to locate and correct the leaks in the cabling, and while this effort was underway, the medium-gain antenna system was used for satellite tracking. Because of the lower gain of this antenna system, many of the pictures received exhibited a comparatively high noise level. On October 14, the General Bronze antenna was returned to service. High winds on October 17 made it necessary to stow the antenna during one scheduled pass.

The inexperience of the new ground station personnel was evident throughout November. The number of tracking difficulties and operational errors remained comparatively high. The quality of the photographic work performed at the station improved considerably during this same period.

Local radio frequency interference (RFI) affected the received TV and telemetry data during November. During that month, local RFI measurements were conducted at Wallops Island in connection with a comprehensive study of RFI in the general area. Reference signals generated for this study affected TIROS TV data on November 13 through November 15. The quality of photographic processing at the station remained high during November.

The general performance of the Wallops Island station was very good during December, 1964. During this period, this station had the best record of the three CDA stations for accurate clock sets. The quality of photographic processing remained high during December.

From January 2 to January 7 the medium-gain antenna system was used because of a failure in the hydraulic drive system of the General Bronze antenna. As previously, the use of the medium gain antenna systems resulted in noise on much of the TV data, and in some instances, in unusable data. On January 25, the 2-kw ITA transmitter and the APT Helix antenna were put into service and on January 27, both the General Bronze antenna and the Kennedy antenna were removed from operation for service and repairs. These antenna systems were returned to service on February 13.

The General Bronze antenna was again removed from service (for 4 hours) on April 7 and, beginning April 12, for 2 days. Also during April, TV data was lost due to inaccurate ephemeris data which caused tracking difficulties. On April 15 and April 18, difficulties in the TIROS-unique equipment resulted

in loss of TV data. Severe radar interference experienced in mid-April was attributed to the Naval operations in the area.

The General Bronze antenna was removed from service for repairs from May 10 to May 15. The medium-gain antenna was used with a resulting increase in noisy and unusable TV data.

During June, the performance of this station was generally good. There were some instances of loss of pictures or non-occurrence of remote sequences due to noise or interference, operational errors, and antenna-equipment difficulties. On June 28, the General Bronze 235-Mc antenna was removed from service due to difficulty with the elevation-drive system; however, it was corrected and returned to service later the same day. During the last week of June, some problems were experienced with high-beacon reception from the Kennedy 136-Mc antenna. The trouble was attributed to the coaxial switch, and it was replaced on June 30.

During August, the daily operational assignments were conducted on a satisfactory basis, except that severe local RF interference on the beacon frequencies was observed during the first 10 days of August. The General Bronze receiving antenna was removed from operational status on August 7 because of a malfunction in the azimuth drive system. Necessary repairs were completed, and the unit was returned to service within 8 hours.

The Wallops Island station experienced tracking and antenna difficulties on the occasions during September, 1965. In addition, on five occasions, difficulties with the TIROS-unique equipment accounted for the loss of some TV and telemetry data. TIROS VII CDA operations were conducted on a generally satisfactory basis during October, November, and December, 1965. However, tracking difficulties resulted in the loss of some TV data on five occasions and telemetry data on three occasions.

c. PMR Ground Station

In early December, 1963, a thorough check of all systems was completed at the Pacific Missile Range (PMR) ground station, and the station was determined to be in complete readiness for the forthcoming TIROS VIII launch. The tracking programming, and data receiving and processing capabilities of the overall system were demonstrated in the station's daily use in the TIROS VII program.

The PMR ground station was equipped with the necessary APT ground equipment. This equipment was modified before launch to provide means for

recording and playing back APT signals using an Ampex PR-10-2 0.25-inch tape recorder.

Following the TIROS VIII launch, the PMR ground station acquired the beacon signals on schedule and at the azimuth indicated in the ephemeris data. Shortly thereafter, the station confirmed separation of the third-stage rocket from the satellite. Spin-down of the satellite was also confirmed at this time, and the resultant spin rate was calculated to be approximately 104. rpm.

The PMR ground station first interrogated TIROS VIII on orbit 002 and successfully received and recorded camera subsystem No. 1 TV data, and telemetry and attitude data. The first APT picture readout at PMR was received on orbit 020. However, because the antenna elevation was only 12.7 degrees, the contact time was sufficient for the recording of only one picture. Higher antenna-elevation angles occurred on subsequent orbits.

Radar interference was experienced during January. Interference occurred frequently when naval operations were conducted near the San Nicolas Island site.

A new antenna/command van was received at San Nicolas Island during March. The new van provided a separate mount for the command antenna and eliminated the cabling problems which had been encountered frequently while the command antenna was mounted on the periphery of the 60-foot reflector. The new transmitter van was completely wired and the two command transmitters installed and checked out during April.

On May 20, a drive belt in the AT-36 nutator assembly broke, causing the loss of auto-track capability. High winds prevented repairs until May 22. During this period, the antenna programmer was used, permitting satellite tracking operations to continue.

Substantial radar interference was again experienced during the period from June 10 to 15, but picture usability was not significantly impaired. Between July 17 and 19, interference from an unknown source was experienced on TIROS VIII video signals.

A new, government-furnished equipment van was installed at San Nicolas Island on August 21, and the TIROS station was removed from operation to permit relocation of the equipment to the new van and modification of the equipment for the dual-TIROS Wheel program. This effort was completed on August 31.

The microwave link used to transmit data from San Nicolas Island to Point Mugu caused serious fades in the signal level of transmitted data during August. In

early August, the effectiveness of data transmission degraded to such a degree that data had to be retransmitted a number of times before a complete sequence of pictures could be obtained. Problems related to the microwave link (between the San Nicolas Island site and the Point Mugu site) received attention from cognizant Navy groups during September.

In the early part of October, the two digital command programmers were installed in cabinet racks mounted in the new van at San Nicolas Island. The station was relieved from routine interrogation schedules during the period from October 6 to 8 to enable installation and checkout of the programmers and training of personnel.

Some improvements in operation of the microwave link between San Nicolas Island and Point Mugu was noted after repairs to the link were effected by cognizant Navy agencies. However, some degree of signal fading continued to be evident when adverse atmospheric conditions were present. The microwave link continued to be a limiting factor on performance at this site. The Navy also began using the TV channel for other operations, causing conflicts with TIROS schedules.

On January 9, 1965, a break in the nutator belt of the AT-36 antenna prevented the use of the antenna for automatic tracking. The cause of the problem was corrected in 36 hours. On January 23, the PMR station experienced a loss of command capability because of a faulty antenna rotary joint. A suitable replacement was not available until February. To circumvent this problem until a replacement for the rotary joint could be obtained, the command transmitter was connected to the antenna by coaxial cable and the station returned to operation on January 25.

On February 3, the new rotary joint was installed on the AT-36 antenna, but the PMR ground station still experienced command difficulties. Investigation revealed that moisture had accumulated in the new rotary joint, as it had in the old one. The new rotary joint was removed and the coaxial cabling reinstalled. The new joint was disassembled and cleaned and reinstalled on the antenna by February 13, after which normal operation was resumed.

By direction from NASA on March 19, the PMR ground station operations were curtailed in preparation for complete discontinuance of operation by April 14. The station ceased operations one day early, on April 13. The ground station equipment was shipped to AED early in May.

d. Alaska Station

The Fairbanks ground station was fully operational for the TIROS VII launch. The modifications to the APT equipment which were necessary to accommodate the Ampex PR-10-2 0.25-inch tape recorder were made at this

ground station. All systems were checked out; and the satellite was passively tracked on orbit 003, then interrogated on orbit 004. All parts of the program were executed during the interrogation; however, no playback was received from camera subsystem No. 1 in response to the command. The satellite was interrogated again on orbit 005, with normal performance, including the receipt of APT data. After the normal interrogation on orbit 006, emergency telemetry was commanded and the satellite temperature and the battery voltage were determined to be within normal limits.

The APT transmission received at this station had a 100-microvolt signal strength as indicated on the APT receiver. No line-of-sight problems were encountered with APT reception.

Operations at this ground station were adversely affected by local auroral disturbances during January 1964. Deep fades on the TV carriers were observed during an aurora display on January 18. During early March, command-frequency interference was detected in the television, horizon-scanner, and telemetry data. Immediate investigation into this problem revealed a defective cable between the transmitter and the antenna. The replacement of this cable on March 3 eliminated the interference problem.

An 85-foot antenna installed at the Weather Bureau site was placed in service with the Fairbanks CDA station on May 19. This antenna was used for approximately one month during modification of the antenna at the CDA site. The control system for the temporary antenna required operating procedures which differed considerably from those used with the CDA station antenna. As a result, some tracking difficulty was experienced during the last part of May. However, by the end of the month, operational errors diminished as personnel became familiar with the requirements of the substitute system.

Satellite interrogations by the Alaska station were cancelled or rescheduled to other ground stations on June 1 and 9 and on June 11 through 14, because of damage to the main cable running between the ULASKA and GILMOR sites. On May 31, a contractor performing work not associated with the TIROS program cut into the cable. Although the nine Styroflex conductors were damaged extensively, three of them were still partially usable. Two of the conductors were used for limited TIROS operations until June 15, when repairs were completed and normal cable use was restored.

During July, a number of scheduled interrogations of TIROS VIII were cancelled to permit the use of the Alaska facility in support of the Nimbus and OGO projects. On July 15, after command difficulties had been experienced for several days with both TIROS VII and TIROS VIII, a coaxial switch (used to switch the transmitter RF output between the command antenna and the dummy load) was found to be defective. The malfunction in this switch had prevented connection of the transmitter to the antenna.

Modifications to the TIROS antenna at the Alaska ground station were completed during July. On July 28, use of the Nimbus antenna was discontinued and use of the TIROS antenna was resumed. During the first 10 days of August, the TV carrier amplitude received at the Alaska station appeared to be abnormally low, and the recorded TV signals showed simultaneous fades in both the horizontal and vertical components. This problem was not experienced by other Command and Data Acquisition (CDA) stations, and it was, therefore, considered a local station problem. An investigation was started on August 10, when the station was shut down to permit installation of digital command programmers, required for TIROS IX. This investigation revealed that, during the antenna modifications performed by the cognizant Data Acquisition Facility (DAF) personnel, the cables between the summing "T" for the horizontal and vertical dipoles and the hybrid ring had not been cut to the proper lengths. After correction of the cabling problem, the TV signals were received and recorded without difficulty.

TIROS operations at the Alaska CDA ground station were interrupted frequently during the period between September 1 and September 15, while the station was being utilized for launch support for Project OGO and back-up support for the Nimbus operations. During this period, the Packard-Bell computers used to record program tapes directly from the Goddard Space Flight Center by means of Digitronics systems was employed, but the results were less than satisfactory. The necessary repairs were performed on the Packard-Bell computers.

It was observed that the signal level received using the Nimbus antenna during October was lower than that received using the TIROS antenna; the use of the Nimbus antenna accounted for much of the noisy TV data received at the Alaska station in October. When the TIROS antenna was in use, the station TV signal was at the normal level and resulted in satisfactory pictures.

During November, many difficulties were encountered and the station's effect tiveness dropped below the performance levels established previously. Among these difficulties, the most persistent were TIROS equipment malfunctions, antenna system difficulties, and operational errors in connection with both the TIROS equipment and the antenna system.

During December, station performance improved considerably. From December 7 to December 16, station operations were suspended while the CDA station equipment was moved from the ULASKA site to the GILMOR site. Normal station Operation resumed on December 16, after this move had been successfully completed.

Between January 1 and January 4, 1965, the Fairbanks station encountered command interference and some telemetry data was unusable. On January 11, the GILMOR site antenna was removed from operational status for repairs, and the ULASKA site antenna system was placed in operation. The GILMOR antenna was returned to service on January 16, but was removed from service again, from January 24 to January 30. In an effort to reduce command interference, a

separately mounted antenna was put into service on January 25; however, transmitter interference was noted on both the beacon and TV frequencies on January 29 and 30.

During February, the GILMOR facility at the Fairbanks station was used to perform the largest percentage of TIROS interrogations. Despite the increased load, the facility performed effectively, without significant loss of data. During the early part of February, the photographic negatives developed at GILMOR were of low but uniform contrast. Investigation revealed that the chemicals used in the water-treatment system were retarding negative development. The problem was eliminated by using distilled water.

During March, the performance of the Fairbanks station was good with very little loss of data. The antenna systems performed satisfactorily and station operational procedures were good.

Loss of data during April was less than during any preceding month. Some difficulties related to the antenna and data transmitters were encountered during April, with some of these difficulties resulting from inaccurate antenna predictive data.

Transmitter and antenna difficulties caused loss of command or program delay on seven occasions during May. A tracking-schedule error caused loss of TIROS VII data on May 19. Photographic negatives and prints processed at the GILMOR facility continued to be of good quality and well within TIROS specifications.

The performance of this station during June was generally good. There were some instances of loss of picture or non-occurrence of remote sequences; these instances were due to noise or interference, operational errors, and antenna-equipment difficulties.

All operations were conducted on a satisfactory basis throughout July. Starting on July 8, this station participated in phase 2 of the Remote Operation Experiment (ROE) by transmitting TIROS TV data to U.S. Weather Bureau at Suitland, Maryland, over the existing wideband communications link.

TIROS VII CDA operations at this station continued without interruption during August; however, minor antenna difficulties affected the operation on August 24. On August 23, the GILMOR antenna was removed from service for repairs and calibration. Because of difficulties with the ITA transmitters and associated transmission lines at the higher output rating, command to TIROS satellites was transferred on August 27 to the 5-kw transmitters and Satan antenna at the new Rose Creek command site. Performance of the new command facilities was satisfactory through the remainder of August.

The Satan 5-kw transmitter command system was used to command TIROS VII throughout September, except during the period from September 17 to 23, when the ITA transmitters were used. During that period the Satan system was removed from operational status for maintenance and system check-out purposes.

Operations during October were conducted in a very satisfactory manner, and loss of data due to station operations was minimal. Repairs and recalibration of the GILMOR 85-foot receiving antenna were completed on October 4, and the antenna was used for satellite interrogation on that date. However, difficulties developed in the Y-axis drive system which necessitated additional repairs and a further shut-down of the antenna. These repairs were completed, and the unit was returned to operational status on October 7.

The minor TIROS operational and equipment difficulties experienced during November are partially attributed to new personnel at the ground station. However, as these new crew members gained experience, the difficulties decreased.

Under phase 2 of the ROE project, all TV data was transmitted over the wide-band data link to the Environmental Science Services Administration (ESSA), during December. On December 2, the 85-foot receiving antenna at GILMOR was damaged and was taken out of service until December 6. Normal operations were continued during this period using the ULASKA antenna facilities.

e. Princeton Backup Station

The ground station at the AED Space Center, Princeton, New Jersey, was used as a back-up CDA station and as an evaluation for TIROS VIII operations. Preliminary work for the installation of an APT ground station was begun in August 1963, and the installation of equipment in an APT ground station van (Government-furnished equipment) was started in September. The overall effort for this installation included laying a concrete foundation for the APT antenna, erecting a fence around the antenna, digging a 300-foot trench to bury the required signal and power cables, constructing a roadway to the antenna site, and moving the APT van to a site near the existing antenna van. By the end of October, the two racks of equipment comprising the APT ground station had been installed in the APT van. Power and telephone connections were also completed with the TIROS ground station. Following the completion of this work, the APT equipment was checked. In November 1963, a Muirhead "Foto-Fax" machine, a tape recorder, and an oscilloscope with a Polaroid camera attachment were installed for use in the post-launch evaluation of the APT subsystem.

In May 1963, AED personnel attended a seminar on operation and maintenance of the APT ground equipment. In November, along with personnel from the three

primary ground stations, they received additional, special training in operation and maintenance of the APT equipment.

Preparations for the TIROS VIII launch were begun on December 1, after the completion of the test and calibration of spacecraft F8, in which the ground station equipment was used. On December 2, NASA requested an extensive modification to adapt the APT ground station equipment to the use of Ampex PR-10-2 recorders; this modification was completed on December 5. The modification was tested, using a demonstration-model tape recorder available at that time; new PR-10-2 tape recorders were received on December 7. Five calibration tapes were made on that day, using one of the new tape recorders and the demonstration model. A "reproduce" head cable on the second of the new tape recorders was found to be reversed, and this condition was corrected on December 9.

Set-up of the APT van at the Princeton ground station was initiated on December 9, and completed on December 14. This effort included adding various units, providing for the two Ampex recorders, and setting up the distribution panel for the three facsimile recorders. A method for calibrating the RF signal level was devised and checked out. On December 10, the Muirhead facsimile equipment was added to the van, but this equipment was not completely installed until December 14. Two of the Ampex PR-10-2 recorders were used to record the control tone for the Fairchild recorder (120-pps input) on one set of tapes and the 1000-cps control tone for the Muirhead recorder on the other.

Preparation of the regular TIROS portion of the ground-station equipment started with repairs to the General Bronze antenna and its associated equipment. This task was scheduled to be completed by December 11, but a break in the azimuth drive shaft, on December 10, delayed completion of the effort until December 12. All power supplies in the TIROS portion of the ground station were removed for preventive maintenance and calibration. These efforts were completed and the power supplies were reinstalled on December 5. Work was discontinued from December 9 to 11, because of a schedule shut-down of the air-conditioning facilities. Upon resumption of work, the video calibrator was wired to drive an RF generator in the antenna van in order to provide a means for checking out both the video system and the RF system. Realignment of the attitude-selector system and the monitor system was completed on December 13th.

The APT antenna system was checked by tracking the 136.23-Mc beacon on TIROS VII on December 12 and 13. The repairs to the General Bronze antenna were completed and checked by December 12, using TIROS VII. The operation of this antenna was better than at any previous time. The full TIROS system was checked on two passes on TIROS VII on the evening of December 13. All systems performed satisfactorily.

The APT systems were checked using the Muirhead and Fairchild test sets. To permit comparison of the pictures, the information was recorded on all three facsimile recorders simultaneously. The Muirhead facsimile recorders both experienced starting problems because of the signal level, which is a very critical parameter for these units.

On December 16 all systems and personnel were ready for the launch. After the several postponements of the launch, the station was activated on December 21, at T-minus-120 minutes.

At T-120 minutes on December 21, all systems at the Princeton ground station were operative; and, upon launch, the station provided the planned support. The spin rate of TIROS VIII before despin was determined at this station to be 128 rpm. The satellite was interrogated on orbit 001, and good pictures were received using direct camera sequence I. When the satellite was interrogated on orbit 003, adequate sensitivity of the satellite's receiver was verified.

During TIROS VIII operations, the Princeton CDA station was used to obtain data for engineering investigations of satellite performance as described in the subsystem evaluations contained in this report. These included investigations of satellite tape recorder performance and of the malfunction of telemetry switch No. 2, which are described in Sections V and VII, respectively. The APT ground station was used to carry out an evaluation of the APT subsystem performance and to investigate spurious modulation patterns in the APT pictures, which are described in Section V of this report.

C. TIROS TECHNICAL CONTROL CENTER

1. Introduction

NASA Operations Division, Goddard Space Flight Center functioned as the TIROS Technical Control Center(TTCC) for the TIROS VIII satellite. The duties and responsibilities of the TTCC were as follows:

(1) to accept, analyze, and catalog engineering reports on satellite and ground station conditions;

(2) to accept, analyze, and transmit predictions concerning the locations of feasible photographic areas, the sequence of these areas, and the times when the satellite could be contacted by the ground stations;

(3) to accept daily programming recommendations from the U.S. Weather Bureau;

(4) to decide the actual sequence of operations for each day, after taking into consideration the condition of the power supply and the performance of the satellite and ground stations;

(5) to prepare and transmit specific operating instructions and pertinent acquisition and picture-orientation information to the ground stations;

(6) to accept and review performance reports and significant telemetry data from the CDA stations;

(7) to select and transmit, immediately, instructions required for handling emergency situations; and

(8) to coordinate all TIROS VIII operational phase activities.

2. Performance Evaluation

TTCC continued to perform its functions with good effectiveness during the operational period of TIROS VIII. The effective working relationship established among the CDA stations, NASA groups, AED personnel and TTCC continued during this period.

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